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ABSTRACT

The proceedings of the 21st annual National Cable Television Association convention are presented under the following groupings: short haul microwave systems, satellite/cable system engineering, market studies, FCC (Federal Communications Commission) technical rules and standards, program origination, cable channel allocations, cable system operation, two-way system experience, advanced techniques and design, underground engineering, and multi-channel microwave distribution systems. (RH)

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21st Annual NCTA Convention

OFFICIAL TRANSCRIPT

TECHNICAL VOLUME

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NATIONAL CABLE TELEVISION ASSOCIATION
MAY 14-17, 1972
CONRAD HILTON HOTEL
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TECHNICAL PROGRAM

21st Annual National Cable Television Association Convention

May 14—17, 1972

Conrad Hilton Hotel
Chicago, Illinois

U.S. DEPARTMENT OF HEALTH,
EDUCATION & WELFARE
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SHORT HAUL MICROWAVE SYSTEMS

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New York, New York

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HIGHLIGHTS
TECHNICAL EYE OPENER WORKSHOP

SHORT HAUL MICROWAVE SYSTEMS

Sponsor

Society of Cable Television Engineers

Organizer & Moderator

Roger Wilson
TelePrompTer Corporation
New York, New York

Panelists

A. H. Sonnenschein
Theta-Com
Los Angeles, California

Ted Swanson
Cypress Communications Corp.
Los Angeles, California

Erik Stromsted
Microwave Associates, Inc.
Burlington, Massachusetts

Frank Thatcher
Thatcher Associates
San Francisco, California

Reporter

Frank DeJoy
TelePrompTer Corporation
New York, New York

Great interest in the increased use of microwave in conjunction with individual CATV systems was evident by the (standing room only) attendance, and the variety and quantity of questions asked from the floor.

Mr. Swanson pointed out that the use of microwave dishes with their extremely narrow beam width places a premium on the torsional rigidity of the towers or the support structures on which they are mounted, with many existing towers no doubt inadequate in this regard. He also made the point that mounting dishes of great heights on towers could result in intolerable waveguide losses at transmitter and/or receiver locations.

A very good explanation was provided by Mr. Sonnenschein on how the small amounts of distortion introduced by an amplitude modulated microwave required a very moderate reduction in the amplifier cascade following. He also commented on path distances vs. number of paths from an amplitude modulated transmitter. Two of the basic advantages of an amplitude modulated link is the channel capacity within the existing CARS frequency spectrum and the reduced costs as compared to conventional microwave techniques for a multi-channel system.

Mr. Stromsted described how, by use of cross polarized antenna feeds and advanced filters, his company has been able to nearly double the number of FM microwave channels in the CARS band, an important consideration. He also pointed out the fact that FM microwave operates with appreciably greater output power and larger fade margins than an amplitude modulated system, and hence has its own special uses.

Comments on rain fades vs. path distance and a comparison of fade phenomena in FM vs. AM microwave systems was provided by Mr. Thatcher. He also provided insight on signal to interference and FM threshold numbers in FM systems.

HIGHLIGHTS
TECHNICAL SESSION

SATELLITE/CABLE SYSTEM ENGINEERING

Chairman

Herbert P. Michels
Time-Life Broadcast Inc.
New York, New York

Speakers

Dr. Richard B. Marsten
NASA
Washington, D.C.

Ralph L. Clark
NCTA Consultant
Washington, D.C.

Reporter

Robert Swensen
Comsat
Washington, D.C.

Mr. Michels opened the session with the thought that the introduction of satellite system technology to serve a portion of the United States telecommunications market will have a major impact on future cable system operations. Program transmissions through the satellite and properly equipped earth stations will be simultaneously available to all CATV operators desiring the service. The key to achieving the impact lies in the development of low-cost earth terminals and will probably involve the use of frequencies in the 11 - 14 GHz range.

1. "The ATS-F Satellite Experiment With Cable TV Distribution" - Dr. Richard B. Marsten

Dr. Marsten first described NASA's contribution to an experiment involving instructional and educational television. NASA will transmit programming material devised by the department of Health, Education and Welfare in conjunction with the Corporation for Public Broadcasting. The NASA earth station at Rosman, N.C., will transmit these programs to the ATS-F satellite (to be launched in the Spring of 1974) which will relay the signals to some 500 small earth stations in the Rocky Mountain region. HEW will provide the small earth stations which will be based on design models developed by NASA.

The ATS-F satellite measures about 52' between the tips of its solar panels; has an antenna which unfurls in space to a diameter of 30', a design life of two years, 500 watts of dc power at end-of-life and weighs 3000 pounds in orbit. The satellite radiates 15 watts of RF power (in the 2.5 to 2.69 GHz band) to provide one program (video plus up to four audio) channel in each of two beams. The beams measure 360 miles in the east-west direction and 450-500 miles in the north-south direction.

The small earth stations used to receive these programs will have 7' antennas and the manufacturers cost is expected to be around $400 - $500 per station. A video signal to noise ratio of 47 db (CCIR weighted) will be provided with a carrier to noise ratio of 15 db. Two-way communication can be provided in the experiment.

Dr. Marsten next offered brief descriptions of future NASA work involving Communications Technology Spacecraft and ATS-Advanced Mission Spacecraft. These spacecraft would investigate system problems with the use of frequencies in the 11 - 14 GHz band and the use of as many as six satellite beams to cover the entire United States.

2. "The Domestic Satellite Characteristics and Opportunities for Cable TV" - Ralph L. Clark

Mr. Clark began his talk by stressing three major obstacles to the beginning of satellite service to CATV operations. All eventually are economic problems. All satellite systems have high fixed costs which must be shared by many different kinds of users in order to economically provide the services the CATV operators require. In a similar fashion the costs of the required earth stations must be shared by many users or they must be cheap enough to permit individual ownership. Lastly, the programming material to be transmitted via the satellite system must be provided by someone.

Any satellite system will involve expenditures of more than $100 million, much of which must be spent years prior to any system revenues. The existing global satellite system may not serve as a useful model for a United States domestic satellite system. The global system uses frequencies (4 - 6 GHz) that are shared with the common carriers and thus are limited in the amount of power they may radiate. (Higher spacecraft power can result in lower earth station performance requirements which might, in turn, reduce total system costs.)

The FCC is currently reviewing 8 applications to provide satellite system facilities for the domestic markets. If all applications were granted, the total in-orbit capacity would approximate 600 transponders each capable of relaying a video program. Since almost all applicants envision serving the same users, the FCC staff recommended that restrictions be placed on a number of applicants to prevent a serious over-supply of available capacity. There are some present indications that the Commission might, however, adopt a less restrictive policy.

SATELLITE/CABLE SYSTEM ENGINEERING SESSION

CHAIRMAN MICHELS: Our subject today is particularly appropriate for the first technical session, since it perhaps holds the greatest potential for the challenge in our industry, satellite program distribution. Now, for the first time, National CATV networks are, on a practical basis, able to distribute programming by satellites on both a technical feasibility basis and an economic feasibility basis, we hope, within a very short time.

This morning we will discuss the first planned experiments in a domestic satellite television distribution system, that is, the ATS-F program sponsored by NASA. We are particularly fortunate to have two experts in the satellite communications field this morning. One is Dr. Richard Marsten and the other is Mr. Ralph Clark, and we will discuss more about those two gentlemen in just a few minutes.

The CATV industry is particularly concerned in the technical configuration of any satellite system proposed by the applicants to the FCC. Of importance to our industry is our ability to benefit from the new technology to the maximum extent. CATV tends to differ in its requirements than other types of communications proposed for a satellite system. Our needs are predominantly one-way in nature; that is, a basic program distribution from a major communications center in the country to many receiving locations. This lends itself to a higher power satellite generally and, in turn, will allow lower cost receivers, and this is probably the only way a national CATV distribution system could be established whereby each CATV system would have a receiving terminal at its headend.

Our first speaker this morning is Dr. Richard Marsten. Dr. Marsten will discuss the ATS-F satellite program and particularly the experience in the Rocky Mountain region and possibly the Appalachian region. I say possibly because it's uncertain as to whether the satellite communications service will be distributed to the Appalachian region at the present time. This will be the distribution of public broadcast service both directly to schools and institutions and also through cable TV, and, to a lesser extent, an experiment with direct satellite-to-home communications.

This is a milestone experience in its initial opportunity of the cable industry to demonstrate the feasibility of this kind of operation for a high quality nationwide program distribution.

Dr. Richard Marsten was with RCA for 13 years. He served as manager of space communications and spacecraft electronic activities in the Astro Electronics Division and was appointed Division Chief Engineer in 1967. During this time he had technical management responsibility for communications and electronic systems and equipment design on Tiros, Relay, Ranger, Nimbus, SERT, and Lunar Orbiter spacecraft and overall engineering design responsibility for Tiros-M.

In 1967 he was a member of the Broadcast Panel of the National Academy of Sciences Summer Study on Space Applications and in 1968 chairman of the Panel on Point-to-Point Communications. He has held national committee posts in the AIAA where he was chairman of the technical committee on communications systems in 1968 and 1969 and technical specialty group coordinator for information systems during 1970.

He is a Fellow of the IEEE and a member of the policy board of the IEEE Communications Society.

Since 1969, Dr. Marsten has been Director of Communications Programs in NASA's Office of Applications.

In discussion the overall subject of satellite communications and in particular the respective proposals to the FCC of the various satellite applicants, we have Mr. Ralph Clark.

Mr. Ralph Clark was retired from service with the federal government in 1970. His last position was as acting associate director of international communications in the Office of Telecommunications Policy, Executive Office of the President. He had been with the predecessor organization since 1962.

Prior to that time he had served with the FCC and in a number of different defense agencies. He has been concerned with communications satellites, particularly from the beginning, having had the defense projects under his guidance in the early 1960s and has been a member of the executive office committee which drafted the Comsat legislation.

THE ATS-F SATELLITE EXPERIMENT WITH CABLE TV DISTRIBUTION

Dr. Richard B. Marsten
Director
Communications Programs
Office of Applications
NASA
Washington, D.C.

The ATS-F (applications technology satellite F) experiment in the Rocky Mountains is a joint experiment for which NASA is supplying satellite channel capacity to the Department of Health, Education and Welfare and associated local groups in the Rocky Mountain Federation of States.

This is part of NASA's general policy of making available satellite capacity we have to interested users: to provide them with experience in satellite communications operations and to give them an opportunity to experiment generally with the kinds of things that this technology helps to do well.

The burden of proposing sensible experiments, of developing and supporting the ground system and of operating the experiment rests with the user.

The ATS-F experiment is a departure in one new way. ATS-F is still in development. It will be launched in the early spring of 1974 and we were approached by HEW and the Corporation for Public Broadcasting together to ask if we would provide them with capacity to conduct a series of community broadcast experiments in public service, in education, in health teleconferencing and an assortment of other things.

Although we didn't have plans at the time for broadcasting in the appropriate bands, we agreed to the experiment and have since incorporated this capability into the satellite for the user's benefit.

I want to emphasize at the outset, to dispel what's a prevalent misconception, that NASA is not in any broadcasting or operational business and that this experiment is not a direct-to-home broadcast experiment.

Figure 1 is a series of notes to the frequency rules and regulations governing the various kinds of services. The broadcast satellite service is a general class in which the kind of experiment that we are going to work with HEW and CPB would fall when the experimental results are extrapolated to someone's operational system.

There is provision here for "individual reception." This is reception by simple domestic installations, and for community reception, which is the reception of broadcast signals by community receivers for local redistribution or for community viewing, as in a town meeting. This is the kind of reception the ATS-F experiments will provide.

The second important item (Figure 2) is that the band in which these experiments will be run is the 2500-to-2690 megahertz band, which is allocated exclusively to instructional and educational broadcasting. It is not available for commercial satellite communications and it's not available for generalized commercial broadcasting. This band is restricted primarily to public service uses such as education and instruction and, in a manner of speaking, health services where they relate to education and instruction.

Figure 2 shows all of the bands that are allocated in some way to broadcast services. The 11.7-to-12.5 gigahertz band is allocated to generalized broadcast services but must be shared coequally with the commercial satellite services of the Intelsat/ Comsat kind, which don't necessarily envision broadcasting to anybody but do embrace telephony, telegraphy and communications of record.

Figure 3 is a photograph of a full-scale model of ATS-F. It is large. From tip to tip of the solar panels is 52 feet. The diameter of the deployed antenna is 30 feet, and the antenna is not extended until after the satellite is launched free of the booster and deployed in orbit. It's wound around a hub in a very tightly coiled spring arrangement and uncoils and erects in space.

From edge to edge of the equipment module at the bottom of the truss we measure 64 inches. The satellite weighs approximately a ton and a half and the power at the end of its two-year life is to be approximately 500 DC watts, available at the output terminals of the solar array. That converts to some smaller number, perhaps 80 watts at the 860-megahertz frequency and, for our purposes, 15 watts for each of two channels in the instructional TV broadcast band at 2500-to-2690 megahertz.

Figure 4 is a cartoon of the kind of experiment we expect to do with HEW and CPB. The satellite itself is placed in an equatorial orbit at an altitude of 22,300 miles. At that magic altitude it rotates once a day with the earth and so appears to be stationary over the equatorial trace on which it is parked. Therefore, you can get 24-hour coverage of any particular area toward which the satellite is pointed.

The satellite is visible over a very large surface region. We can see it from our control station at Rosman, North Carolina. The Rosman station is the standard operating site for control and all experiment operations of ATS-F.

The satellite itself is accessed through an uplink in the commercial communications band at 6 gigahertz. We can transmit anything compatible with the satellite receiver up that link; the receiver has approximately 500 megahertz bandwidth.

ATS-F can transmit down at a number of frequencies, some of which are in the 2500-to-2690 band, and those frequencies will be used to illuminate areas in the Rocky Mountain region and/or in Alaska, depending on how HEW allocates the time for its user experiments and how the various uses are disposed over the available time and power in the satellite.

We do not expect to provide signals for both rebroadcasting from local stations which will be equipped with ground receivers and distribution from cable head ends which may be equipped with ground receivers. We would also expect to provide, in rural towns, villages, regions where there aren't any available coverages either from cable or from broadcast stations, signals for direct village distribution from the local ground receiver that is supplied there.

HEW intends to procure and deploy approximately 500 of these small ground receivers.

We expect also to provide some back-links so that experiments can be done in interactive services. One-way service experiments are not very useful for determining attractive applications in education and health care information delivery, where future demands point to interaction and broad band. So we have to have voice back link capability, in which the access back to the satellite will be provided on a different but related frequency, in the same general frequency region, through the small ground stations.

Figure 5 shows the pairs of footprints that can be made available from the satellite in the Rocky Mountain region. We have two beams, each of which will provide a full TV channel with as many as four simultaneous audio links. The satellite antenna pattern is configured to produce one north-south pair only. The position of the pair on the ground can be changed by pointing the satellite where coverage is desired.

The area covered is approximately 360 miles east-west by 450 miles north-south in the lower beam and about 500 miles north-south in the upper beam. The elongation is due to the angular squint: the satellite is not looking down the nadir perpendicular to the surface, but is squinting upward from the equatorial plane to illuminate the Rocky Mountain region at an angle to the surface.

Figure 5 also shows the locations of some of the rebroadcast stations. These are Public Broadcast Service stations. Notice that in some areas (in Wyoming, for example, and in Montana) there aren't any Public Broadcast Stations at all. There may be some cable systems there that are interested in cooperating with the experiment.

To work with the satellite, we have developed an experimental model of a small ground station. Figure 6 is a photograph of the station that was developed at Stanford University under NASA sponsorship. It operates in the general S band region from about 2200-to-2700 megahertz. The antenna is made of flat stock, force-bent to a frame. It's very inexpensive. Two technicians can assemble it within two hours when it is delivered in boxes with the sections stacked.

The diameter of the antenna is 10 feet tip to tip. In the photograph the seams of one of the sectors are visible. The sectors are cut so that when bent to the frame they form a parabolic antenna. Above the reflector, behind its feed, is the entire electronics: a parametric amplifier or a tunnel diode front end, modulation converter and output cable. The cable may be connected wherever it will have to go, either to the cable system headend for redistribution or to conventional receivers to feed into the turret or on a particular standard TV channel.

We use FM with approximately 25 megahertz total bandwidth for the signal. Four audio channels are provided, each in its own subcarrier. The four audio subcarriers each deviate the video carrier by about 490 kilohertz of peak audio deviation to its particular subcarrier. The four subcarriers are multiplexed with the video so that the whole signal package, video plus four audio channels, takes up 25 megahertz. These characteristics are for reception only. The NASA development has not addressed the problem of interactive talk-back capability. We have done this development to demonstrate what could be done and to show that it can be used with signals of appropriate small flux density. We have made and will continue to make the technology available to interested parties; it is in the public domain.

This technology is currently being used by HEW-CPB to go out on procurement for their 500 ground stations to their own design, which includes interactive talk-back capability for up to 50 voice channels.

Figure 7 shows some results of cost-size tradeoff studies to determine whether we really were in the right ballpark with the station sizing that we chose. We did this both at 860 megahertz, which is the frequency of a like experiment we have agreed to conduct with the Government of India in the second year of satellite life, and at 2500 megahertz.

In the figure we polt the gain-to-noise ratio of the receiver as a function of the antenna size and then determine, as best we could, what the ground station costs would be for some moderate quantity as a function of that ratio. In both cases, the cost minima occur about at the 3-meter size.

The situation is a little bit more flexible as the frequency goes lower, but 2500-2690 megahertz is the frequency band of interest in the United States, so we feel we are close enough to the bottom with our engineering model development to have substantially chosen the low-cost development about where it could be most attractive.

We have obtained preliminary estimates of what these stations would cost in quantity. The estimates are supplied by people who are in the production business, such as GE, Hoffman Electronics, others who make this kind of equipment in their normal business operations. In quantities of up to a thousand, the ground station of Figure 6 would run in the neighborhood of $500 emplaced. That's not a lot of money. It compares with the approximately $100,000 to $250,000 that one would have to pay for a 30-foot ground station to work television distribution with current commercial satellite designs of the domestic satellite variety that have been proposed. (Some cable operations could afford the more expensive approach but they would be operating still in the commercial satellite communication bands, not in the educational bands, so that is not relevant to our experiment.)

Figure 8 is a photograph of the NASA-developed engineering model of antenna electronics, showing the exterior or antenna unit and the indoor unit that is fed by the modulation converter on the antenna in both rear and front views.

Figure 9 shows the characteristics of the complete, experimental receiving system that we chose to do at 2.6 gigahertz, FM, 25-megahertz bandwidth, no tuning. It is a fixed, single-channel receiver.

The noise figure in the model we developed was 7 db. The 7 db can be achieved with a 39-cent transistor in the front end. A two-dollar transistor can be used to reduce the noise figure to 5 db. If one goes to more elaborate things such as an HP-21, the noise figure can be brought down to about 2 or 3 db but the cost of that device is $21. One can see where volume manufacturers might have difficulty coming to terms with that kind of component cost in the development and manufacture of low-cost systems.

Working with the experimental transmission capability of ATS-F, this set of characteristics leads to an output picture quality of 47 db CCIR weighted. This quality picture can be rebroadcast, can be redistributed, and will still yield a good deal better result than one is accustomed to on the home set most of the time. That quality is better than TASO-1. The experiment technical quality was designed this way deliberately because we do notwant the HEW-CPB experiment to be signal-limited. This is not typical of what one might approach or want to provide in an operational system, because the objective of the ATS-F experiments with HEW and CPB is not to show that we can communicate by satellite -- I think the Comsat/Intelsat system demonstrates that quite handily -- but to provide a capacity on which experiments of use can be conducted without complaints about the signal quality.

That summarizes the HEW-CPB experiments. They will be working with some 500 assorted towns, villages, cable headends and broadcasters. They will be experimenting in one-way and two-way education delivery, the kinds of programming that are effective, the methods of use or delivery that are effective, and how to mix CAI with more or less standard programming in audio/video.

The health people will be experimenting with off-campus professional education connecting the four medical schools in the region with advanced students at remote health stations for actual video instruction and,,in some cases, with two-way video remote diagnosis and prescription.

Figure 10 shows an artist's picture of the Communications Technology Satellite we are developing in concert with the Canadian government. This satellite is the first development inhthe 11-to-13 gigahertz band, where there is a larger application for broadcasting than in the instructional band at 2-1/2 gigahertz. The satellite will have the capability of providing one or two video channels sequentially across the country of Canada or, alternatively, across the entire United States, in a beam covering about 1/3 of the country at a time. We intend to launch it about the middle of 1975. Time for user experiments will be shared equally between the United States and Canada.

This satellite is intended not only to develop the technology, but to provide capacity for uses. Figure 11 lists the kinds of things we would like to demonstrate in making the satellite capacity available to interested users who wish to propose experiments.

The importance of this new development is that the band is available for both broadcasting and commercial satellite communication. At the 12 gigahertz frequencies one could conceivably work with an antenna as small as 2 feet in diameter and, once again, the development objective is to provide an inexpensive, relatively foolproof receiver that will stand up in remote regions and deliver a good quality signal.

Finally, since neither the ATS-F experiments nor the proposed experiments on the Communications Technology Satellite provide simultaneous, multiple-beam capability, it will become important to investigate the flexibility and the technology associated with the simultaneous coverage this capability could provide to different, geographically separate regions.

Figure 12 shows an artist's concept of one approach to multiple-beam capability that we are studying for possible launch by about 1977 or '78. The intent is to have as many as six beams which could be used simultaneously to cover the continental regions of the country, Alaska, and Hawaii; and to make available within each of those beams a number of channels. So this is, in a sense, the technology of the middle future in satellite communications. High power for multiple channels within a beam, multiple beams with footprints that are contoured to represent more closely the time zones, for example, or other geographical regions they wouldiilluminate and, again, for flexibility in experiments.

BROADCASTING SATELLITE SERVICE

THIS IS A NEW SERVICE WHICH IS NOW DEFINED AS SHOWN BELOW:

MOD 84AP Broadcasting Satellite Service

A radiocommunication service in which signals transmitted or retransmitted by space stations are intended for direct reception (1) by the general public.

ADD 84APA Individual reception (In the Broadcasting Satellite Service)

The reception of emissions from a Broadcasting Satellite space station by simple domestic installations and in particular those possessing small antennae.

ADD 84 APB Community reception (In the Broadcasting Satellite Service)

The reception of emissions from a Broadcasting Satellite space station by receiving equipment, which in some cases may be complex and have antennae larger than those used for individual reception, and intended for use:

- By a group of the general public at one location, or
- Through a distribution system covering a limited area.

ADD 84AP. 1 [1] In the Broadcasting Satellite Service, the term "Direct Reception" shall encompass both individual reception and community reception.

NASA HQ EC72-15902 (1)
5-4-72

Figure 1

BROADCASTING SATELLITE SERVICE

Summary

THIS NEW SERVICE WAS DEFINED AND AUTHORIZED IN THE FOLLOWING FREQUENCY BANDS:

620 - 790 MHz	Footnote status with PFD * limits and qualifying footnotes
845 - 935 MHz	Final protocol reservation permitting experimentation in India with PFD limits and qualifying footnotes
2500 - 2690 MHz	Primary shared allocation, with PFD limits and qualifying footnotes
11.7 - 12.2 GHz	Primary shared allocation, with qualifying footnotes limiting service to domestic systems in Region 2
12.2 - 12.5 GHz	Primary shared allocation, in Region 1 only with qualifying footnotes
22.5 - 23^0 GHz	Primary shared allocation, in Region 3 only, with PFD limits
41 - 43 GHz	Exclusive allocation, world wide
84 - 86 GHz	Exclusive allocation, world wide

* Power Flux Density

NASA HQ EC72-15901 (1)
5-4-72

Figure 2

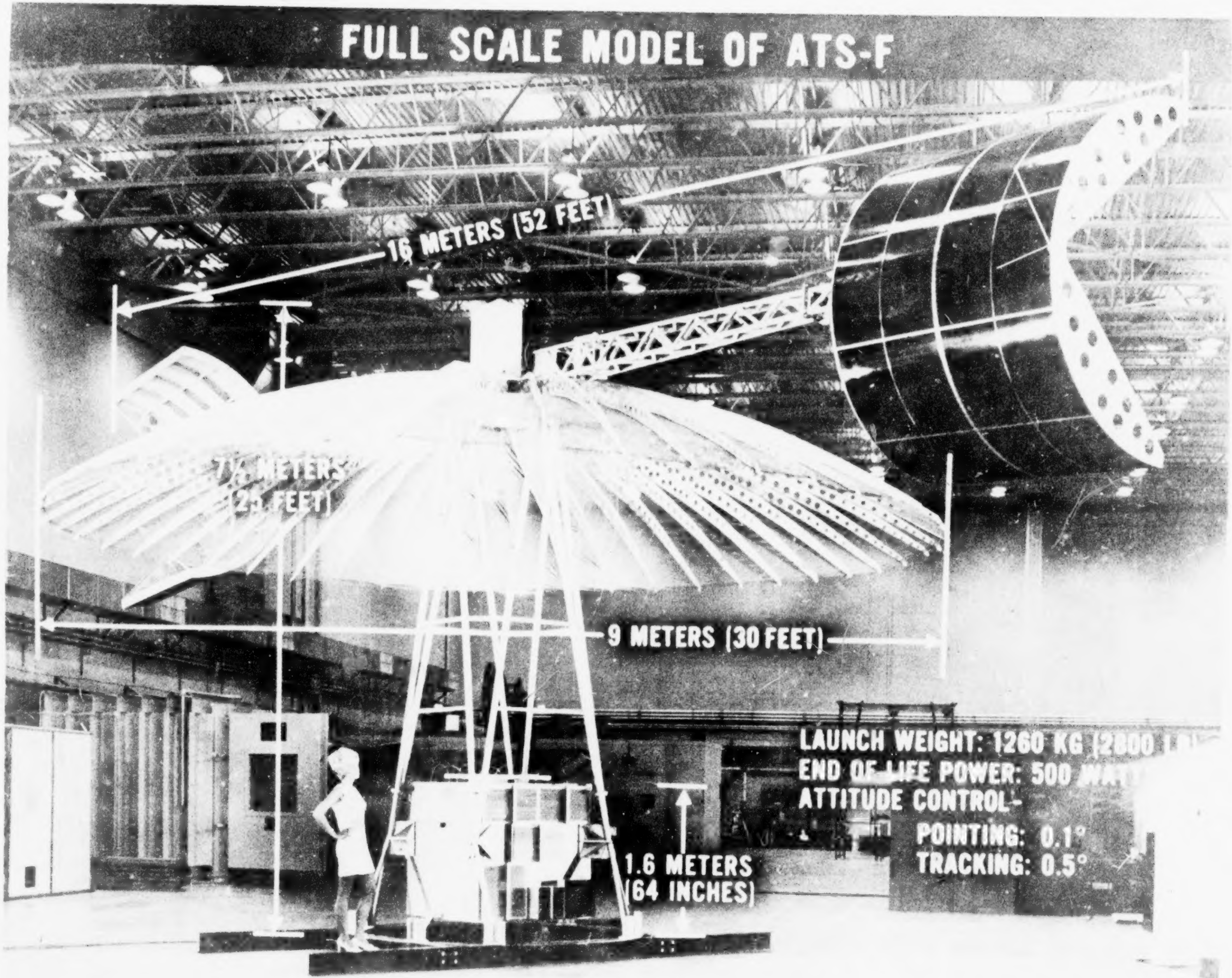
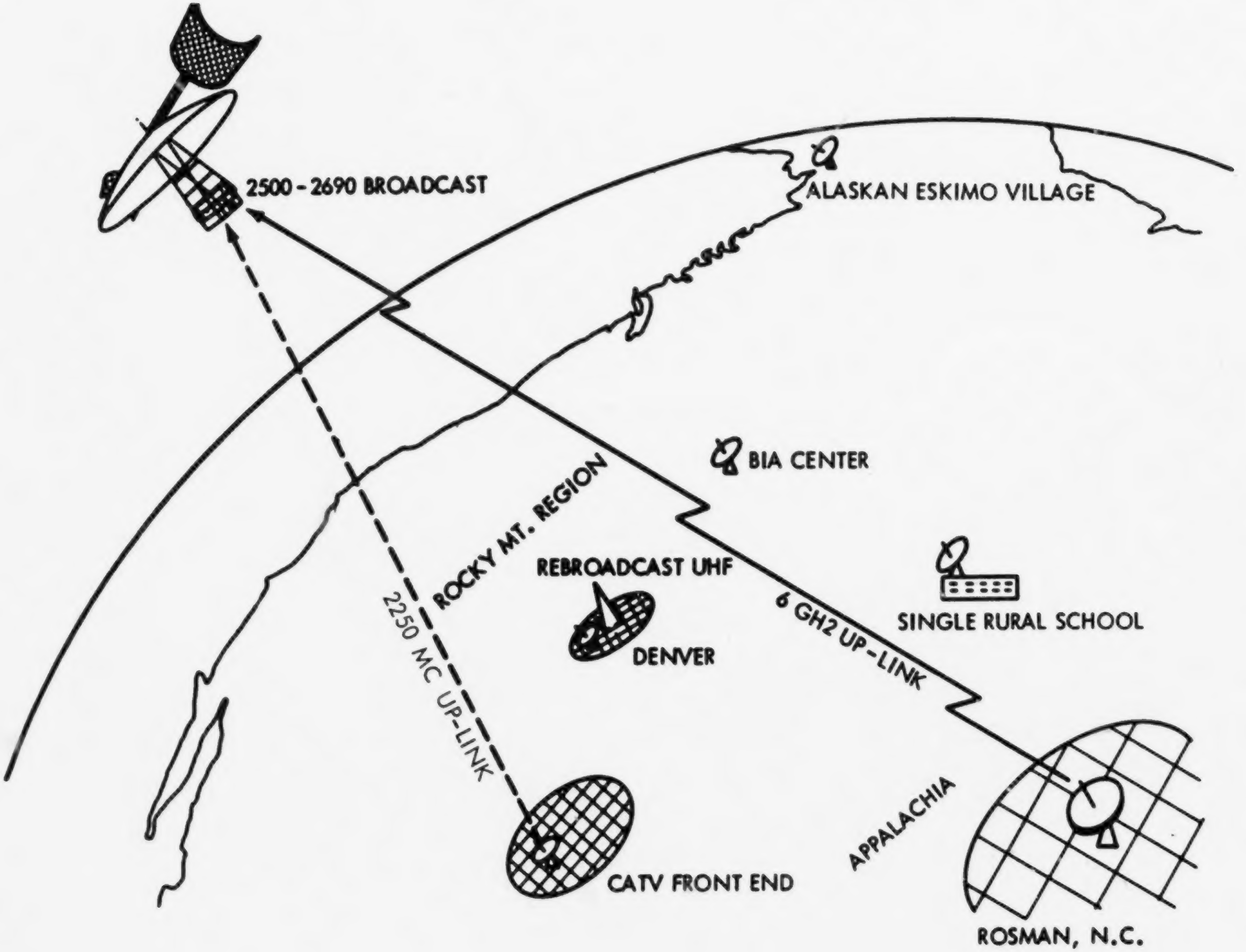

FULL SCALE MODEL OF ATS-F
16 METERS (52 FEET)
7½ METERS (25 FEET)
9 METERS (30 FEET)
1.6 METERS (64 INCHES)
LAUNCH WEIGHT: 1260 KG (2800
END OF LIFE POWER: 500
ATTITUDE CONTROL-
POINTING: 0.1°
TRACKING: 0.5°

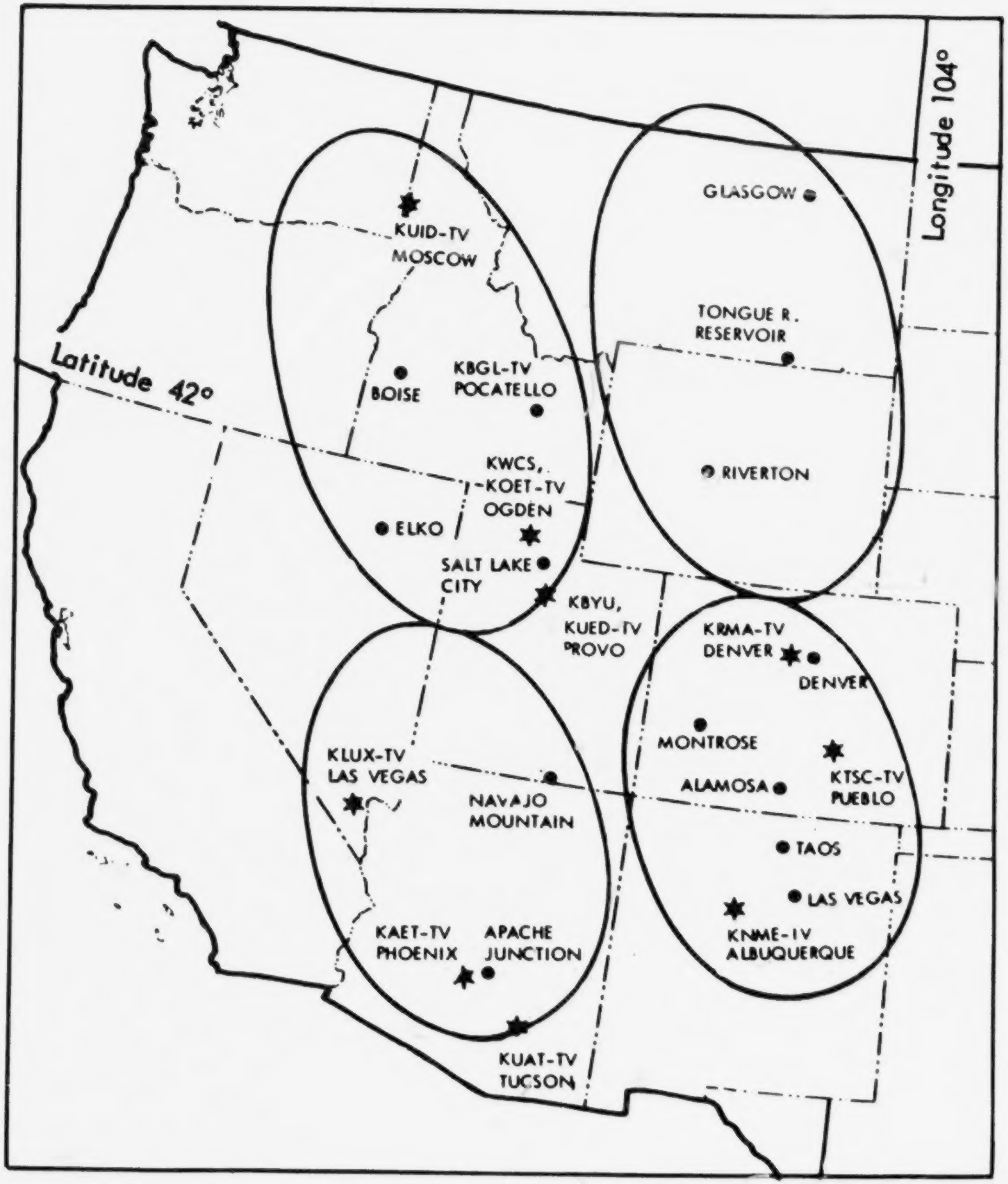
Figure 3

SYSTEM CONCEPT FOR 1973-1974 ATS-F EXPERIMENT


2500 - 2690 BROADCAST
ALASKAN ESKIMO VILLAGE
BIA CENTER
ROCKY MT. REGION
REBROADCAST UHF
DENVER
SINGLE RURAL SCHOOL
6 GH2 UP-LINK
2250 MC UP-LINK
APPALACHIA
CATV FRONT END
ROSMAN, N.C.

NASA HQ EC72-15923 (1)
Rev. 6-8-72

Figure 4


Longitude 104°
Latitude 42°
KUID-TV
MOSCOW
BOISE
KBGL-TV
POCATELLO
KWCS,
KOET-TV
OGDEN
ELKO
SALT LAKE
CITY
KBYU,
KUED-TV
PROVO
GLASGOW
TONGUE R.
RESERVOIR
RIVERTON
KRMA-TV
DENVER
DENVER
MONTROSE
ALAMOSA
KTSC-TV
PUEBLO
TAOS
LAS VEGAS
KNME-TV
ALBUQUERQUE
KLUX-TV
LAS VEGAS
NAVAJO
MOUNTAIN
KAET-TV
PHOENIX
APACHE
JUNCTION
KUAT-TV
TUCSON

NASA HQ EC72-15922 (1)
5-22-72

Figure 5

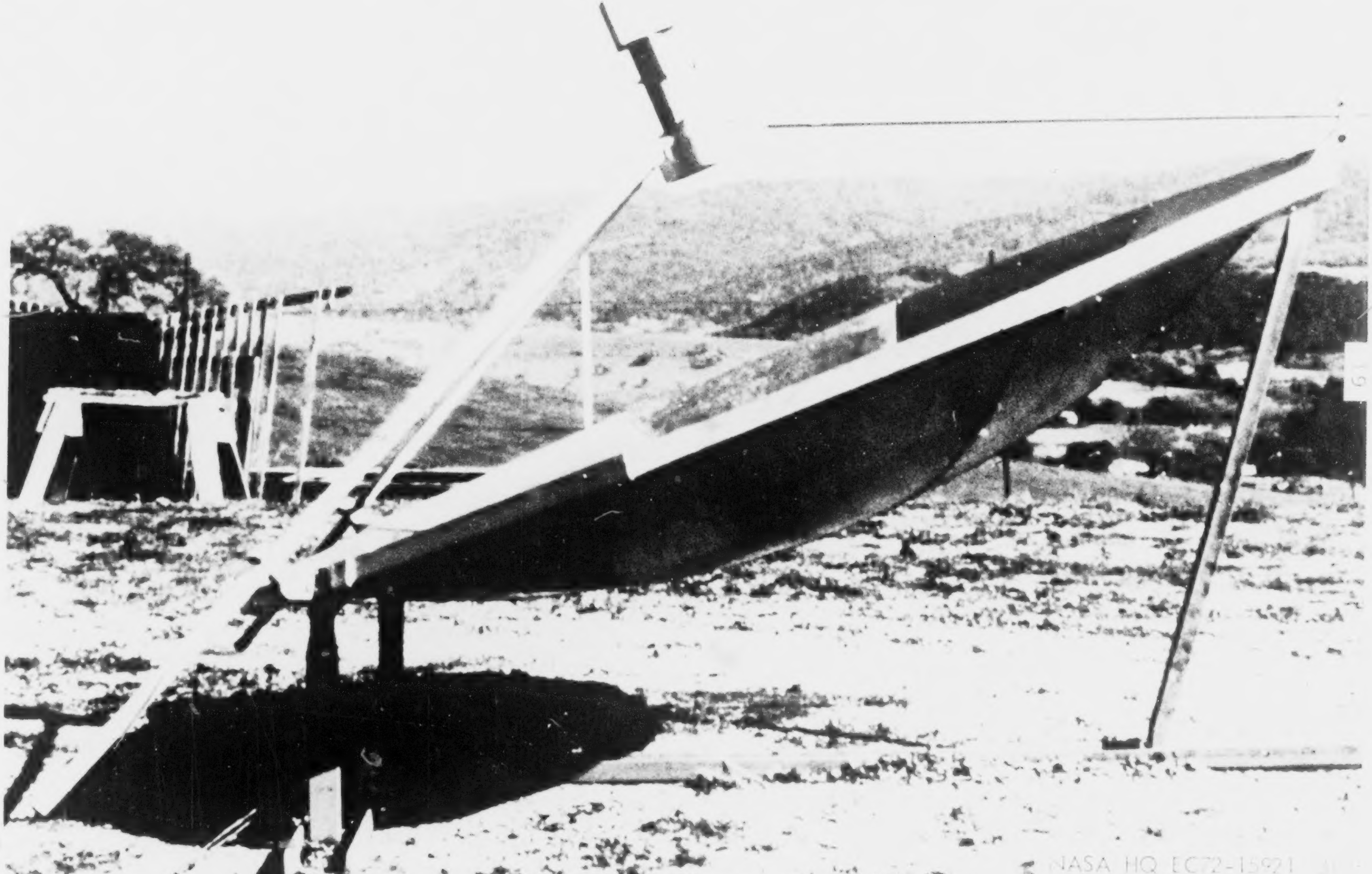


Figure 6

NASA HQ EC72-1592l
5-22-72

GROUND STATION COSTS, SYSTEM NOISE TEMPERATURE

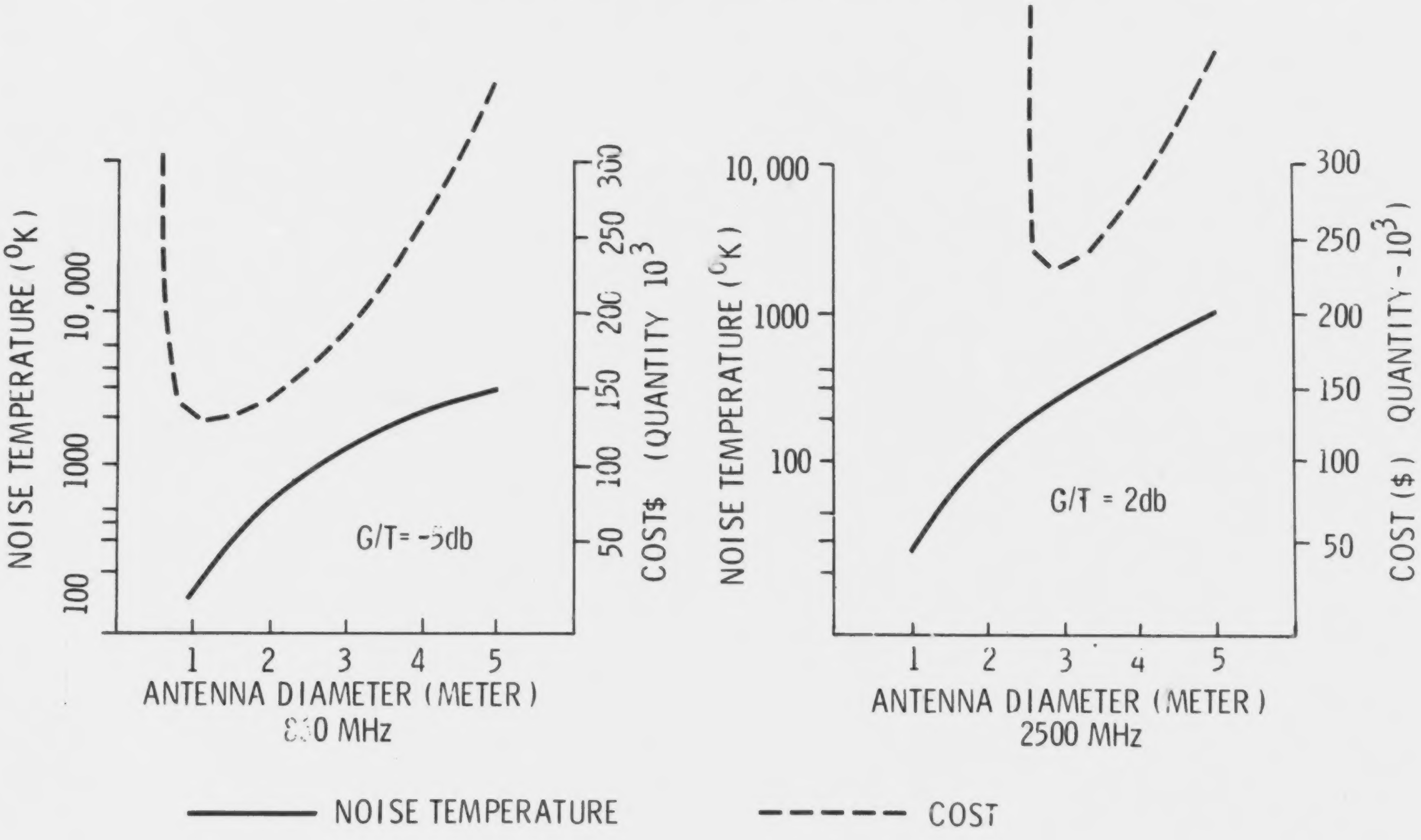


Figure 7

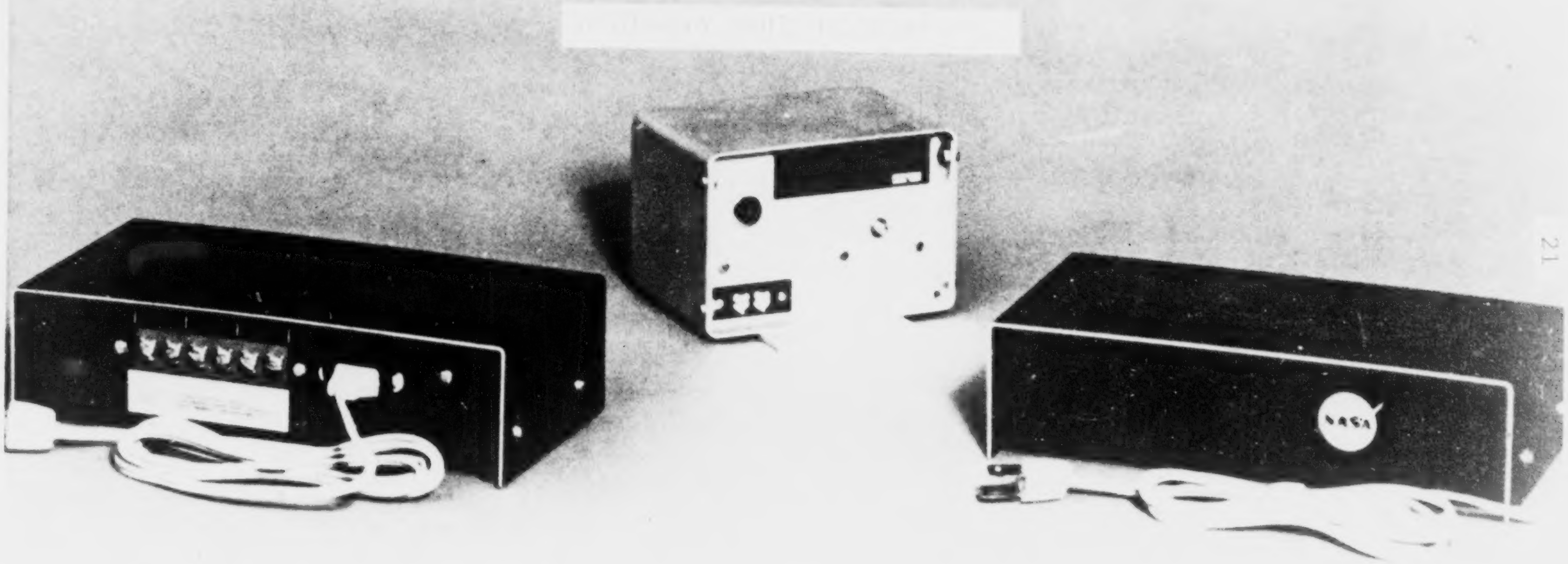


Figure 8

RECEIVING SYSTEM CHARACTERISTICS

FREQUENCY	2.62 GHz
MODULATION TYPE	FM
SIGNAL BANDWIDTH	25 MHz
RF TUNING	NONE
RECEIVER NOISE FIGURE	7 dB
ANTENNA DIAM	2.1 m (7 FT)
ANTENNA GAIN	32 dB
ANTENNA EFFICIENCY	55%
RECEIVING SYSTEM G/T	0.4 dB
VIDEO S/N (CCIR WEIGHTED)	47 dB (AT C/N = 15 dB)
RECEIVER OUTPUT	VHF/AM-VSB

NASA HQ EC72-15925 (1)
5-22-72

Figure 9

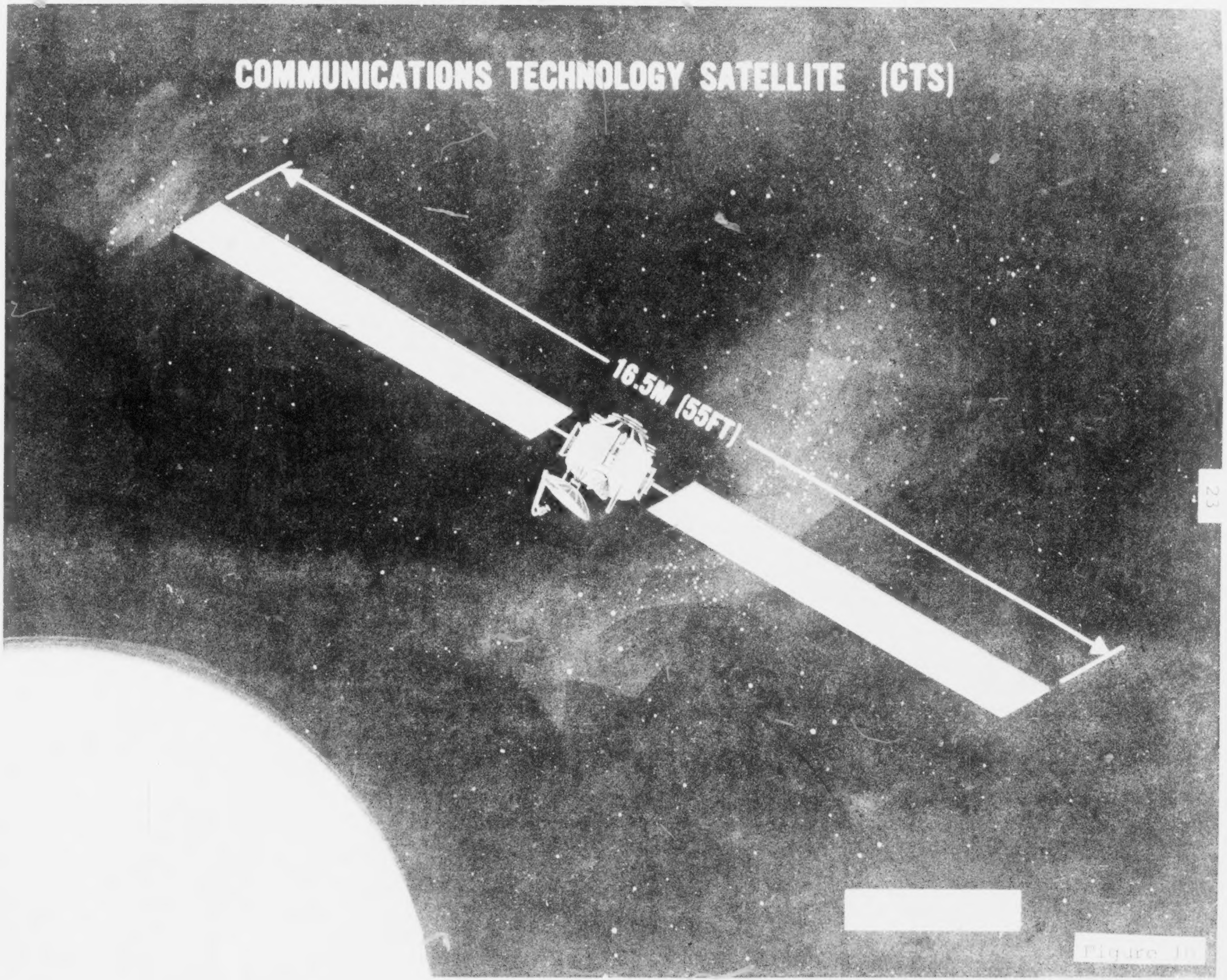
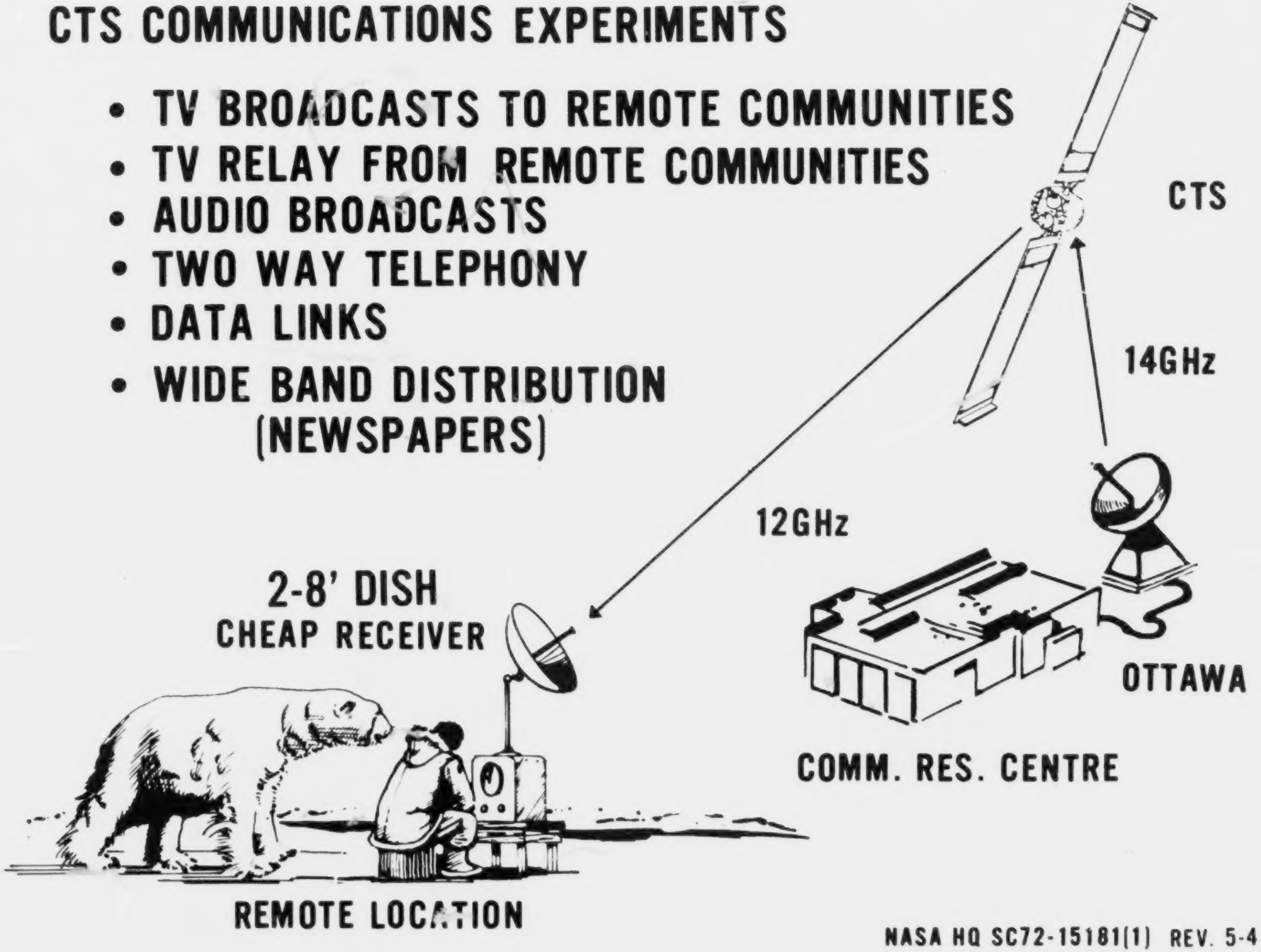

COMMUNICATIONS TECHNOLOGY SATELLITE (CTS)
16.5M (55FT)

Figure 11

CTS COMMUNICATIONS EXPERIMENTS

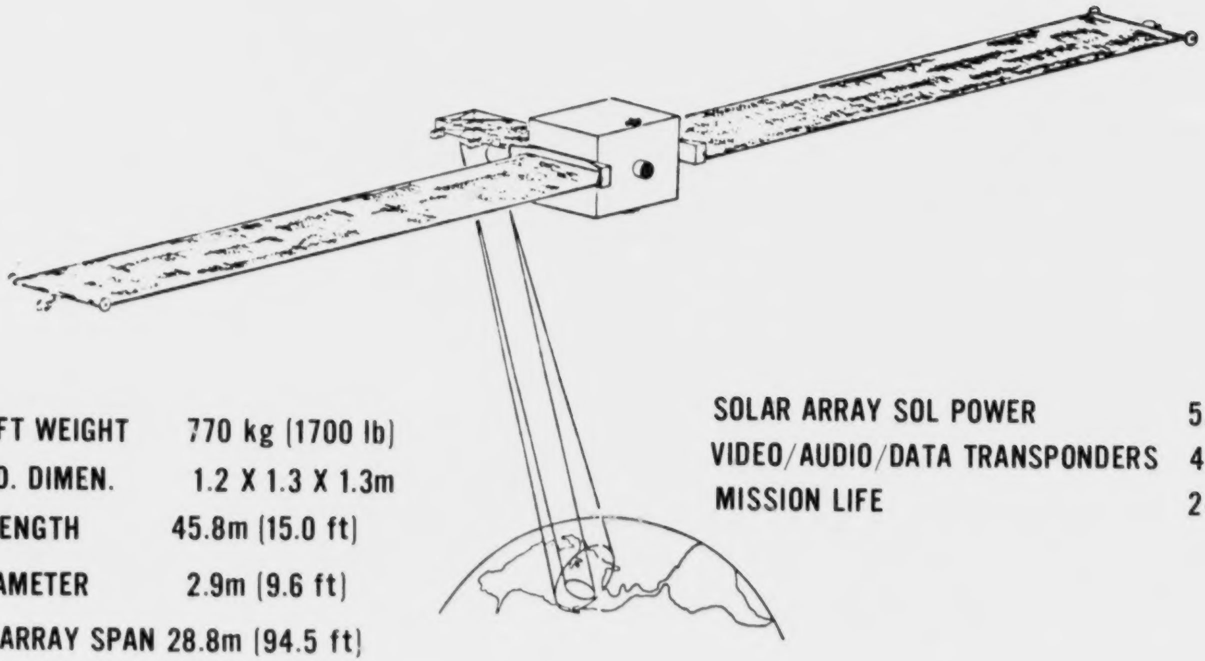
- TV BROADCASTS TO REMOTE COMMUNITIES
- TV RELAY FROM REMOTE COMMUNITIES
- AUDIO BROADCASTS
- TWO WAY TELEPHONY
- DATA LINKS
- WIDE BAND DISTRIBUTION (NEWSPAPERS)


CTS
14GHz
12GHz
2-8' DISH
CHEAP RECEIVER
OTTAWA
COMM. RES. CENTRE
REMOTE LOCATION

NASA HQ SC72-15181(1) REV. 5-4-72

Figure 11

ATS - ADVANCED MISSION SPACECRAFT II
(Direct Ascent - SLV3D/Centaur D-1A/Burner II Launched)
SUN ORIENTED



SPACECRAFT WEIGHT	770 kg (1700 lb)
EQUIP. MOD. DIMEN.	1.2 X 1.3 X 1.3m
OVERALL LENGTH	45.8m (15.0 ft)
FOLDED DIAMETER	2.9m (9.6 ft)
EXTENDED ARRAY SPAN	28.8m (94.5 ft)

SOLAR ARRAY SOL POWER	5.5 kW
VIDEO/AUDIO/DATA TRANSPONDERS	4
MISSION LIFE	2-5 YEARS

NASA HQ EC72-15898 (1)
5-4-72

Figure 12

THE DOMESTIC SATELLITE CHARACTERISTICS AND OPPORTUNITIES FOR CABLE TV

Ralph L. Clark
NCTA Consultant
Washington, D.C.

For some of us who were in the Eye Opener Session this morning, you will have to forgive me but this is somewhat repetitious but I think it will be useful for the subsequent discussion and there are many new faces here that weren't with us at eight o'clock. I'm not sure my eyes were open myself. Maybe I didn't see all of you.

Somebody said that he was there with toothpicks to keep his eyes open and somebody else said that would show all the red eyeballs.

The development of the potential of domestic communications satellite systems for enhancing the services of cable television systems faces a number of major obstacles before there is any promise of financial return for us in these services. It's not just a chicken and egg problem but we've got at least a three-cornered problem. We've got interlocking activities which will require substantial commitments of resources before a program service via satellite can be available to cable system subscribers.

First, there will have to be the satellite system which, to be economically viable, will have to be part of a system established to satisfy other communications requirements. In other words, if we are going to use a few transponders for cable program relay, these will have to be carried as part of a bigger system that is serving other needs also.

There will have to be a set of earth stations which serve a number of communications activities or, hopefully, are economically viable as a separate entity so that we can each have an earth station at our headends.

Then there will have to be a program service or services provided to make use of this system.

Each of these three separate parts of the service will involve commitments of hundreds of thousands or a few million dollars before there is any payoff in sight. If we address ourselves to the satellite portion of the system first, we need to look at the current state of affairs with regard to proposals which could lead to a satellite transmission capability to meet our needs. Many look at the successful international communications satellite system operated by Comsat for the international consortium Intelsat and say, "Why can't we use a system like that?"

There are major obstacles to the successful direct conversion of the international system to domestic services. The frequencies used by Intelsat, which were agreed to internationally during the extraordinary administrative radio conference in 1961, are shared with extensive terrestrial microwave systems which necessitates rather stringent limitations on the signal intensities that satellites can lay down on the ground to avoid interference to these existing microwave systems.

The TD-2 system, which is the backbone of the common carrier microwave relay system in this country, operates in these same bands, 4 and 6 GHz.

This is not a great handicap for the international system which is set up primarily to provide a large number of telephone channels and a few television channels between countries where the demands are relatively large. The fact that an Intelsat earth station costs several million dollars to work effectively at these low signal levels does not provide the same obstacle to an effective economic system that would be the case of a domestic system desiring to reach a large number of separate terminals with a few channels.

We've even got troubles in the international area where some of the smaller countries that had a few HF channels, possibly 5 to 20, have put in ground stations that cost 6 or $7 million. Now they are trying to run those same channels through the satellite and they've got much better transmission but the cost per channel is ten times what it was with their HF systems. So they are crying about the cost.

Telesat Canada, which is being built to operate in these same frequency bands, is planning a number of receive-only earth stations which I am told are costing about $200,000 each on a turnkey basis. I think they are buying 35 of them. This is a complete station with a building, a power supply and everything but about 200 k.

These stations are configured to handle one or two television programs and they have been engineered to provide this service at about the minimum cost using these frequencies at the present time, that is, in the 4 and 6 gigahertz bands.

Another problem sometimes develops because it's necessary to locate the stations remote from the location where you need the service. Because of possible interference with the surface microwave systems, you may have to locate the station away from the center where service is desired and use microwave relay on other frequencies to tie the station with the load center.

One of the possibilities of reducing the cost of earth stations and thus reducing the cost of the overall system is to use frequencies in bands where satellite services have priority and where they are not restricted in the amount of signal they can lay down on the surface.

The most promising of these bands for television programming distribution to a large number of receive-only earth stations would be the frequencies in 11, 12, 13, and 14 gigahertz, which were approved recently by the Administrative Radio Conference in 1971 for this service. However, the technology necessary for the use of these frequencies is nowhere near as well developed or as well advanced as that for the use of the lower frequencies and, consequently, more development work must be done and there are greater uncertainties as to the costs of quite a few of the components, the ground station and space segment components as well.

As we know, the Federal Communications Commission has had the question of domestic communications satellites under consideration for a long time. Recommendations were made by the Office of Telecommunications Management five or six years ago, as I recall, that a pilot system be established to develop technical and economic information which could guide the country in the exploitation of domestic satellites. As a result of many actions, many proposals and recommendations by various organizations, the situation has gone through a large number of changes.

However, the Commission on March 24, 1970, issued a report and order which resulted in the filing of eight proposals to establish domestic satellite systems and also in several proposals to build independent ground stations. On March 17, 1972, the Commission issued a Memorandum and Order which, in effect, was just a cover letter on top of a set of recommendations of the Common Carrier Bureau of the Commission. Although this report and order did not present a final decision on the subject, it did take a major step toward a plan for the establishment of domestic communications satellite services.

The Commission then asked for comments to be filed by April 19 and provided for oral argument before the Commission en banque on May 1 and 2. So let's look briefly at these proposals -- what the applicants propose and, to some extent, what the Commission staff proposes to do with these applications.

Systems were proposed by Western Union Telegraph Company; Hughes Aircraft Company, with four telephone operating companies of GT&E Service Corporation affiliated; by Western Telecommunications, Inc.; by RCA Global Communications, Inc. and RCA Alaska Communications, Inc.; by Communications Satellite Corporation and AT&T as a team; by Comsat separately; by Lockheed MCI Satellite Corporation; and by Fairchild Industries, Incorporated.

The applications filed by these several companies provide a range of possible services to CATV system operators and a considerable variation in possible business relationships with users.

A most interesting application, from the standpoint of the CATV system operator, is that of Hughes. Hughes proposes a system to generate programs and distribute them for a fee via satellite to CATV operators. Hughes has presented a fee schedule based on a fixed charge for each subscriber to a CATV system. Quoted fees have ranged from 25 cents per month per subscriber to $2.00 per month per subscriber, depending on the amount of service the CATV operator got from Hughes, the type of programming, and so on.

Hughes' proposal also would provide long-haul communications relay for GT&E. It contemplates major earth stations in the vicinity of New York and Los Angeles with receive-only earth stations that could be located close to CATV headends.

These stations would use 35-foot diameter non-tracking antennas -- that would be a fixed antenna somewhat similar to this ATS-F experiment -- with feed arrangements which would permit a switch to an alternate satellite when one satellite passes before the sun. In other words, at certain times of the year the satellite will pass across the face of the sun and you get noise from the sun and so you would switch to a second satellite and they would put two satellites in orbit to take care of this operation. This switch would only have to be done on a few days twice a year and it could be computer-controlled from a remote location so that it could be done automatically.

Hughes estimates that these stations would cost approximately $100,000 and if they were used for several services the costs could be apportioned between the several users. On the other hand, such stations could be provided for a CATV headend.

Hughes would provide 12 channels per satellite and guarantee 20 channels for the 8 that they have assured GT&E they would provide and 12 channels for video program distribution.

Several of the other applicants before the Commission proposed various video transmission services as part of their total plan. Some give specific attention to the provision of such services to a widely distributed system of receive-only ground stations. RCA, Western Telecommunications and others considered this possibility.

The Comsat application proposed a multi-purpose service that would include CATV systems. It suggested that two television channels would be needed by CATV. Some of us would have doubts that that is going to be enough. Comsat in this application and in subsequent discussions which we have had with the people have opposed the idea of user-owned earth stations dedicated to one service such as CATV operations.

MCI-Lockheed proposes to provide primarily leased telecommunications services. It would provide service for transmission of CATV programming either on an occasional basis or with a full-time dedicated transponder, one TV channel per transponder. Lockheed proposed to establish 15 transmit/receive earth stations at major metropolitan centers which would be program sources and this application proposed the establishment of receive-only ground stations which could be used for CATV service and either owned by Lockheed or by the CATV system.

Fairchild Industries proposed to provide 24 channels for wide area TV coverage of the 48 contiguous states.

Western Union proposed to provide ten full-time channels for video services.

The AT&T-Comsat proposal is for a system dedicated primarily to expanding the existing services that AT&T now provides. It would involve three satellites to be put up and operated by Comsat, and five ground stations. It makes no specific provision for CATV program distribution or for distribution to receive-only earth stations. AT&T does propose to provide adequate circuit capacity in the system for program distribution but it would have to be leased to another operator to provide for CATV use.

No one of these applications, with the possible exception of Fairchild Industries, offers hope of a reasonably economical system for distribution of television programs to CATV headends. Fairchild has quoted prices of from $234,000 to about $360,000 per year per channel, and the rest of the applicants have proposed prices from 75 to $125,000 per month.

Most of them contemplate a channel in the present 4-6 gigahertz bands which will require earth stations, which I estimate and others have will cost 75 to $100,000 each. I mentioned the $200,000 price tag associated with the Telesat Canada station.

The FCC Common Carrier Bureau considered the several applications, the fact that many of them propose services to the same customers, that the economics of communication satellite services are still somewhat uncertain, and that a grant of all of the applications might result in a substantial period of time while the several applicants worked out possible combinations. They have to resolve the problems of financing, they will compete for commitments to provide service to customers, and so on.

The total of these applications would provide about 600 transponders in space and each transponder is capable of carrying a television program in one direction, also capable of carrying 500 to 1000 telephone channels in one direction and a much larger number of narrow band data channels. So there is real question as to whether all of these would provide economically viable systems.

So the staff recommended some groupings of systems that could result in the establishment of possibly three systems. The FCC Common Carrier Bureau suggested that their proposal would permit each applicant to use the satellite technology of its choice without having to invest in a complete system, while at the same time each participant would be free to design its system to attract customers and to devise new services and rates.

The staff further concluded that each participant could use its share of the facilities in whatever manner it desired to develop services and rates and so on.

The Bureau also recommended the imposition of a number of restrictions on the various systems. First, with respect to AT&T, because of its strong position in the market for communications services, the Bureau proposed that AT&T be limited at least in the early years to the use of satellites only for non-competitive services such as the interstate message toll traffic and Wide Area Telephone Service.

The FCC, if it adopts the Bureau's recommendations, would also require AT&T to show that leasing facilities from Comsat was not more costly than owning its own facilities.

With respect to Comsat, the Bureau would require it to choose between owning and operating a space segment for AT&T or owning and operating satellite facilities for furnishing service to others than AT&T. The Bureau said that Comsat should not be in the dual position of providing service to AT&T and also providing service in competition with AT&T.

The Bureau recommended that satellite equipment suppliers who have filed applications would be required to establish a separate corporate subsidiary to provide communication service and they also recommended that whatever services are established the opportunity be provided for users to own their own ground stations.

These recommendations have been considered and a large number of filings were submitted prior to the 19th of April. One of the difficulties we are in here is that we had to prepare some of these talks before the 19th of April and certainly before the 1st of May for inclusion in the conference record and so we're somewhat caught up by the march of events.

A point that the Bureau made in its recommendations as published was that, and I will quote this: "Domestic satellite system licensees should not be required by the Commission, as a matter of policy, to furnish free or reduced rate service to public broadcasting or other eductional users, --"

It further stated "that while the Commission may prescribe such preferential rate treatment, it lacked sufficient information to initiate any such rate requirement at this time."

The Commission in requesting comments and setting the date for oral argument before the Commission on the Bureau's recommendations, asked the several parties to treat particularly the following issues.

First -- Whether the Commission should adopt a policy of limited open entry, which is what the Bureau in effect proposes, or, in the alternative, a policy of unrestricted entry.

Second -- Whether the Commission should require Comsat to elect between owning and operating a space segment dedicated to the use of AT&T or owning and operating satellite facilities for the purpose of furnishing services to others besides AT&T.

Third -- Whether AT&T should be limited in its use of satellite facilities to just providing its non-competitive services.

Finally -- Whether the Commission, as a matter of policy, should require licensees of satellite facilities to provide free service to educational entities.

The gist of the written and oral responses to these questions seems to be the concept of combinations; that is, limited open entry proposed by the staff will not fly and rumors have it that the Commission will probably adopt some policy such as that recommended by the Office of Telecommunications Policy, which would provide open competition between the several applicants.

The interests in domestic satellite services for CATV may not be necessarily serviced by a wide-open field immediately because there will be a large number of problems to be solved. Since the stakes are high and the potential for losses from misjudgment will be very substantial, services that CATV systems can afford can only be provided as a small part of a much larger system serving a wide variety of telecommunications customers. With the exception of the systems proposed by AT&T-Comsat and the portion of the Hughes proposal that would serve GT&E, no one of these applicants has any assured market for its services and most of them are aiming at a future somewhat nebulous market for specialized communications services. These services are primarily services for business data transmission and getting a commitment to handle the programs of the three commercial TV networks and promoting a wide range of other private line services.

The Commission, in addition, has recently authorized a number of specialized common carriers to build several wide-ranging networks of microwave stations whose owners are proposing to serve the same general markets. Some of us with a good deal of experience in the communications field believe that these markets have been overestimated. I personally believe that inadequate attention has been given to the critical problem of local interconnection arrangements which tie these interesting long-haul microwave systems, whether they are specialized carrier microwave systems or satellite systems, to the desks or the communications terminals of their ultimate users, and it's going to take a lot of subscribers to pay a reasonable return on the hundreds of millions of dollars which are going to be required to build the specialized microwave systems that are now going forward and to establish one or more, two or three domestic communications satellite systems.

Communications satellites hold major promise for distribution of programs to CATV systems. I think that we can convince ourselves that technically we know how to do it, economically we know how to do it, if we can get somebody to put up the satellites, but, nevertheless, there are a good many unknowns before we are going to have a viable domestic communications satellite system that will really serve our CATV needs.

DISCUSSION

CHAIRMAN MICHELS: Thank you, Ralph Clark.

We will open the discussion up to questions at the present time. Do we have anyone with any questions for either of our speakers?

I would like to point out that the major issue with regard to satellites serving CATV at the present time, the major issue is how we are going to serve CATV systems. Are we going to serve them with a conventional type of satellite system that is presently being used in international service right now whereby they are essentially low power systems inter-connected with terrestrial communications systems or are we going to arrange a system whereby satellites will transmit directly to head ends?

These are the questions that the NCTA and the entire cable industry is pondering at the moment.

QUESTION: Mr. Clark, I wondered if you could explain why Fairchild's system is far more economical than the others?

ANSWER: Because they propose to put up 120 transponders in one satellite.

QUESTION: Is there any difference in their ground station or anything else that makes a large difference?

ANSWER: The difference they have quoted is only in the cost of leasing a transponder. They said if they put up one satellite of 120 transponders the cost would be about $300-some-thousand a month -- a year to lease. If they put up two satellites, that would reduce the cost because they would have twice 120 transponders flying.

The cost of ground stations wouldn't be any different because they are in the 4 and 6 gigahertz bands and the limitation on signal intensity on the ground is a function of the band, not a function of the type of transponder.

QUESTION: How would these systems interfere with local community programs or would they be affected?

ANSWER: No, I wouldn't think that they would be -- local community programs wouldn't be affected at all. The ratio of network or satellite-delivered programs to local programs is a function of a decision of the cable operator rather than a function of the distribution system or anything like that. It's a function of the cable operator.

How the cable-distributed programs would be judged under the Commission's new rules, I don't know. I don't know as they have committed themselves as to what they would call a satellite-delivered program. Under these new rules there are certain restrictions on the number of programs that can be carried and the types of programs that can be carried in each metropolitan area. An operator is required to have a substantial number, an equal number of channels for local program service.

QUESTION: So it would depend on the individual with the switch?

ANSWER: That's right.

CHAIRMAN MICHELS: I would presume that the programs carried on the satellite would be in the category of an extension of local origination of some sort.

MR. CLARK: I would think so.

CHAIRMAN MICHELS: So that they would essentially be closed circuit rather than broadcast channels.

MR. CLARK: Right.

QUESTION: There is one question I have for Dr. Marsten. On the one hand you were discussing ground stations costing under a thousand dollars and in some cases two or three hundred, delivering high quality pictures and, on the other hand, Ralph Clark is talking about ground stations costing hundreds of thousands of dollars. This is somewhat of an ambiguity and I think you might address yourself to that.

ANSWER: I'll be glad to do that. Ralph's discussion centering around the hundred thousand dollar and up station deals with just those stations operating in the commercial communications satellite bands where the flux density is limited and where, because it's limited, you have to have a station of that size to get all of the channels that are coming down with adequate signal quality.

The experiment that I described on ATS-F is designed to work in a different band altogether, in the 2500 to 2690 megahertz band where there isn't a limitation on flux density. So we can exchange power and antenna gain focusing capability in the satellite for antenna gain and ground station size and cost, which is what we've done.

Now, the cost that I referred to of 2 to $300 was for the design that we developed, an experimental, receive-only one-channel station, and that's a manufacturer's cost. I didn't say price. What the manufacturers will charge to produce and sell stations that can receive two or more channels and that have a talk-back capability which transmits up to, say, 50 multiplex voice channels at once out of a 10 watt transmitter back to the satellite remains to be seen.

We have some indications that sets of that type might go for 1200 to $1500 a shot emplaced. That's still a lot lower than the $100,000 and up for the commercial communication satellite stations but it's because of the trade of power and gain in the satellite for station size on the ground.

CHAIRMAN MICHELS: I'd like to add the fact that potentially the CATV industry may benefit from these experiments to the extent that ground stations in the lower-cost region could be developed for the frequencies that CATV satellites might eventually use.

Do you agree with that?

DR. MARSTEN: Yes, I think that's quite right. Having demonstrated that the technology is there and such stations can be made, I think it's fairly clear that it can be extended to any frequency band of interest to operators.

The CTS experiment that we are now engaged in with Canada focuses on just that, because the distribution of broadcast signals in the 11 to 14 gigahertz region is also at present unlimited by flux density restrictions and can work with small ground stations.

The fact that you need the FM anyway and the modulation converter in the ground station would tend to make these frequencies attractive for other than educational purposes, so far as cable TV is concerned.

CHAIRMAN MICHELS: Just one final question from me. Do you ever envision a time when, in the foreseeable future, these costs will come down lower than we are looking at at the moment? In other words, even below 2 or $300? Wouldn't that open up the door to direct-to-home communications?

DR. MARSTEN: I guess it could, provided you were willing to receive a non-standard signal and sustain all of the additional complexities and provided my friends over at the FCC would allow it at all.

The frequency bands in which we are developing the technology and the frequency bands currently allocated to satellite communications aren't now intended for direct-to-the-home broadcasting. There is, as the cable TV people know, a broadcasting group that indulges in direct-to-home broadcasting from terrestrial stations that would also take a dim view of this bypassing their local transmitters.

So I think the question isn't just a technical one. The technology is always the easy part. We can do the gadgets without difficulty; it's all the other things. How should they best be used, economically and for the interest of the public? Those are the things that the experiments and the developments should be focusing on.

QUESTION: This will be addressed to Dr. Marsten. After this two-year lifespan of this -- we happen to be in this area and I'm real concerned about this -- what's going to happen for the backup?

ANSWER: I guess all we can go on with a sample of zero of this design is the experience we have with other R&D birds. The ATS-1 satellite is still operating. We are using it almost exclusively now for user experiments with the National Ocenaographic and Atmospheric Administration, with HEW, with the State of Alaska, with Stanford U. and the State of New Mexico and so on. It's in year 7 of its life and it was designed for a life of one year. It's showing signs of age, to be sure, but that's a remarkable pot of gravy to get for a one-year design.

ATS-3 is in a somewhat similar state. It was launched a year later and it's in year 5-1/2 or 6 of its one-year design of life.

We would hope, though, -- I can't make any guarantees -- that after the second year when we move in back from India, the satellite will still be serviceable and we can make it available to users.

We also have plans for a G which will back up F and which will be launched about a year to 15 months later.

QUESTION: Okay then, what's the interface? In other words, are you going to go down to composite video at the receive location?

ANSWER: I think that's up to the user. What we provide is the technology and the capability. We won't dictate to you how to use the satellite or what the technical interface has to be. If you can provide at the Rosman station a signal that we can modulate on our carrier and transmit, we'll take it. We have taken these from the Corporation for Public Broadcasting and experiments with ATS-1, we are taking them in all kinds of forms from HEW now for health and educational experiments. So it's pretty much up to you.

Really, here, the thing that's important is to determine what this technology means to the way you develop program material and how that in turn may or may not affect your signal interfaces. That's the effective use of this stuff.

QUESTION: Is that umbrella antenna going to work when it goes up?

ANSWER: Oh, yes. Oh, yes, sure.

QUESTION: Has this been done before?

ANSWER: Yes, yes. When I was at RCA we had a 10-foot deployable antenna which we contributed -- well, contributed isn't quite the right word -- but we developed for the Apollo Program and it's been used. It's an S-band antenna and works fine.

QUESTION: I did arrive late so I hope I'm not asking a question that has been answered. The present issue of Electronic Technicians Magazine has an article about Irving Blonder discussing the Canadian satellite system, which has a down frequency of 4 gigahertz, and he comments in the article that there is nothing in the present FCC regulations that would prevent reception and use of this signal on cable systems in northern United States.

The beam width is 7-1/2 degrees, which would place a reasonable signal over Montana, Wyoming, and Minnesota.

Do you foresee the use of this signal as a possibility?

The second part of my question: What is modulation?

ANSWER: Yes, I guess, from a technical point of view, there isn't a problem if you want to invest in an appropriate ground receiver to take it. What he's describing is not the CTS that I talked about; it's the Canadian Telesat System, which is a satellite of the Intelsat or proposed domestic satellite design. It does operate in the 4 and 6 gigahertz bands and you can get it but I think you need a fairly elaborate ground station to get it.

QUESTION: He used a 2 or $300 price but I've never heard of a 4 gigaHertz receiver from anybody at that price.

ANSWER: I don't know of one myself. He may know something I don't, which isn't an unusual situation.

CHAIRMAN MICHELS: I think you've raised more of a legal question than a technological one anyway.

MR. CLARK: There would have to be an agreement worked out with the Canadian Broadcasting Corporation, I think.

CHAIRMAN MICHELS: Yes. You would be transmitting copyrighted material and so one and there would be a question there.

QUESTION: Considering all the economic and technological and political uncertainties that have been mentioned, would either or both of you care to take a crystal ball and look at how these distribution systems are going to look in, say, 10 years or even 20 years?

MR. CLARK: I think we'll have plenty of them in 10 years but how we get from here to there is -- the road isn't very clear yet. I feel very confident that in 10 years we'll have this problem solved. We'll have a new set of problems. We'll have satellite relay of programs to CATV systems, a very well integrated system.

DR. MARSTEN: Dean Burch, in his testimony to the Senate of last August, indicated that in his view it's much too early to say what form the networking of CATV systems will take. It's too early because there is so much discussion of this wide variety of services for which there isn't a visible market.

We talk about education in the home, we talk about teleconferencing, we talk about automatic shopping and banking and all the rest of these interactive services and there have been in fact a number of studies done asking people what they would be willing to pay, given ranges for the various kinds of services.

What we need and haven't yet is live field trials which follow up with offerings of subscriber services to the public either after they've had samples or at the time they are explosed to samples, to see whether the polling theory is matched by the experimental evidence of the checkbooks. Until we get that, we're not even going to know whether local wide band systems in metropolitan areas are viable. Can they survive economically? What services make sense and what services don't?

Until we know that, we are not really going to have a handle on the operational channel capacity that this general kind of system can support economically and, if you don't have that in local areas, it seems to me a bit premature to say, "Let's configure a satellite system for national interconnection."

QUESTION: Dr. Marsten, could you elaborate a little on the two-way capabilities that you are building into the ATS-F, that is, the uplink from the remote stations?

ANSWER: Sure. The ATS-F has an experiment in satellite tracking and data relay and, while I don't really want to go into the details of that, what it means so far as cable is concerned is that there are one or two 10 megahertz-wide receiving channels in the satellite that operate at either 2075 or 2265 megahertz. Now, the HEW-CPB experiment envisions multiplexing back out of something like 10 or 20 watts transmitting capability in the small cheap ground stations as many as 50 equivalent voice channels. Those transmitted up to the satellite can be received and then retransmitted back down on some link. We're not concerned whether it's the 4 gigaHertz downlink or an S-band to whatever central processing station is indicated.

Now, more than this I guess I can't say because the actual experiment plan is up to the user and we expect that the education people, the Rocky Mountain people, the health people, together with the National Library of Medicine and the villages and the local health complexes and health maintenance organizations in the

Rocky Mountain area will develop their own particular experiment plans for where they want the backward, down transmissions to come.

But we do have these 10 megahertz-wide capabilities and they are being specified into the small ground stations.

I guess, to tie back to a question of yours, Herb, I ought to say that when you add the capability for transmitting back up into these small ground stations and you equip them to receive on two beams rather than one, the manufacturing cost is no longer a couple of hundred dollars, it may be closer to 7 or 8 and you may find that the installed cost is about 1500 bucks a shot.

CHAIRMAN MICHELS: I have one question here. When you mention 50 voice channels, and this question is only in regard to a domestic, within the continental limits of the United States, what is the logic to going to all the trouble of putting a voice channel back up on a satellite and back down again, when you can call from New York to Chicago or New York to California for about a dollar for three minutes?

ANSWER: I guess, as the HEW people see it, when you are conducting experiments with Pueblo Indian villages and other places like those, from an educational center at, for example, the University of Colorado, you may not have a telephone circuit available when you want to get from 30 or 40 different classrooms in that particular experiment, real time, interactive educational experiments. That's the reason for this.

You can apply the same sort of thing to CAI. In fact, we now have a primitive link between a Pueblo village and Stanford U. which is exploring the potential of computer-aided instruction with the Indians of that region where the native language isn't English.

QUESTION: I have a technical question. I notice that you use FM for the video modulation. As you know, all commercial television is AM modulated. Do you convert to FM going up to the satellite and then back down by FM and then convert it back to AM because you get much less noise problem with FM?

ANSWER: We get two things with FM: one is less noise and the other is substantial processing gain that substitutes for real power. This starts when you look at what's required to transmit an NTSC signal down from the satellite. If you were going to transmit that down in any of these bands, you would end up requiring 3 to 5 kilowatts of RF power per channel in this satellite. With the FM I can do it with 15 watts of RF power, and satellites too cost a lot of money so we want to limit our investment.

QUESTION: I wonder if Dr. Marsten can comment on a satellite which would be a community broadcast satellite suitable for rural areas for augmenting their front end and getting good service for a few hundred dollars and the same service, the same program service would be used for CATV for distribution in the cities.

There must be a very large number of rural homes, percentage of rural homes that have really got bad service now and this would be one method of really fixing it.

ANSWER: I don't really know quite what to say. Certainly you can do this. The technology is here. Some of the things that will be demonstrated in the ATS-F experiment will indeed show that you get this kind of community service with high quality signals into the rural areas. If you can do this in the rural areas, there is no reason at all why you can't do it in the cities. The same sort of receiver with the satellite capability to transmit to it at the same time will serve the purpose. Now it's just a question of what you build into the satellite.

Fairchild Industries, in their domestic filing, has proposed one version of this and many other people intheir literature have proposed others. The futuristic look thatII showed at the end of what we call the ATS-H and -I is an experimental approach to just that kind of thing.

QUESTION: My question would be to Dr. Marsten and to Mr. Clark. It is about a worldwide TV coverage. First I would like to know if there is a European satellite and also if there is a plan for something for Asia or maybe even more difficult, Africa?

Secondly, I would like to know if there is a status agreement on sharing a satellite between the foreign countries? There is one in Canada but is there one about Europe and the European countries?

Also, I would like to know the future of worldwide TV from different countries as we do now with shortwave, with one video channel from some of the main countries and broadcasting in different languages that we could choose from?

CHAIRMAN MICHELS: Those are very interesting questions. We'll try our best to answer them quickly but we don't have much time left and I'm sure we could devote a whole program to them.

QUESTION: I'd like to add one point. I know that there was a tentative agreement between Quebec Province and France on some sharing, that kind of future broadcasting.

CHAIRMAN MICHELS: Ralph, would you like to address yourself to that?

MR. CLARK: Yes. There is international relay of television now through the Intelsat satellite system. There is a plan under way for the so-called Symphony System, which is a European regional system, which is, I might say, kind of limping along because the question of how it is going to be launched and how soon it's going to be ready is still uncertain.

I'm not sure I recall the other aspects of the question.

CHAIRMAN MICHELS: I would like to point out to the person asking the question that this panel is mainly dedicated to the engineering aspects of satellites and the question you raise is more of an administrative question.

QUESTION: Along the line of what you infer, I would like to know what are your opinions about the near future of worldwide TV receiving ability?

ANSWER: There is no plan for direct broadcasting to home receivers. Now, there are these experiments that Dr. Marsten described, the Indian experiment, and so on.

QUESTION: I am not aiming especially at home receivers, but I am aiming expecially between different countries.

ANSWER: There is the relay through Intelsat almost every day. We see television programs that have been relayed from somewhere overseas, from Viet Nam, from Japan, from Korea, and so on.

QUESTION: I think now the drawback is that there are not enough communications satellites yet and the price is not --

CHAIRMAN MICHELS: I don't mean to interrupt your question, but, really, this question is addressed to the wrong group. We are primarily concerned with the technical aspects and not these other aspects that you are discussing. There is another satellite meeting at the Convention that will discuss these other features, the full access to the satellites and other things of that nature.

Are there any other questions? We're rather short of time. We have room for one more, if there were.

Thank you very much, ladies and gentlemen, for coming and the meeting is now adjourned.

HIGHLIGHTS
TECHNICAL SESSION

BLUE SKY TO CASH FLOW

Chairman

Hubert J. Schlafly
TelePrompTer Corp.
New York, New York

Speakers

Dr. Peter C. Goldmark
Goldmark Communications Corp.
Stamford, Connecticut

John J. O'Neill
The MITRE Corp.
McLean, Virginia

John Ward
Electronics Systems Lab., MIT
Cambridge, Massachusetts

Robert Behringer
Theta-Com Corp.
Los Angeles, California

Reporter

Dan Wells
Public Broadcasting Service
Washington, D.C.

1. "National Cable Systems" - Dr. Peter C. Goldmark

A possible nationwide communications network was discussed which would link cable television systems together by means of a domestic satellite. Many services could be made available to the public in any area of the United States which presently are available only to people in metropolitan centers.

In order to meet the urgent problems of the city (crime, pollution, health, etc.), it is essential that significant portions of the population, in the order of 100 million Americans, must be encouraged to stay or move to rural areas to achieve a more uniform population density. (At present, urban centers account for 80 percent of the population and 10 percent of the land.)

To provide this encouragement, rural living must provide employment, health services, and social cultural and recreational facilities. Some of these conditions can come about through the application of communications technology in rural America.

A domestic satellite system can provide the means of interconnection among cable television systems and among broadcast stations to provide these services. The services would be available in the home and also on large video screens in specially adapted theaters.

In order to have an acceptable picture on large screens, the quality of color television must be improved by adopting new standards. The Goldmark Communications Corporation is working on the design and formulation of such standards. The resulting signal will be superior in resolution and color fidelity to existing systems in both the United States and Europe. Receiver manufacturers would be encouraged to adopt a dual standard that could accommodate the existing or new standards.

Question: How can the many diverse cable operators be coalesced into a single national cable system?

Answer: The satellite system will beam the signal across the country. Any cable operator or television station with a suitable receive earth station could pick it up.

Question: Will new color standards make existing television receivers out of date?

Answer: No, because the improved standards will be an additional service. The existing home sets could still receive the present service. Also, of course, programs viewed on video screens in a theater could be viewed by anyone.

2. "CATV's Critical Mass Problem" - John J. O'Neill

Some of the cable television fundamentals recognized by businessmen and bankers are (1) Urban dwellers already receive good quality television pictures and have access to cultural and entertainment events (2) An aggregate set of services that will assure adequate penetration has not been defined and (3) High initial capital investment is needed.

Whether subscriber fees or advertising eventually becomes the prime financial support, the key to an economically viable cable system is high saturation. Initial systems should be designed to encourage the subscriber growth rate, even though the return on investment may be relatively low in the early years.

In rural areas, where television picture quality is marginal and nearby cultural and entertainment opportunities are limited, the penetration may not be very sensitive to the monthly subscriber fee over the range of $3 to $8. In urban areas, the penetration will be very directly influenced by the subscriber fee. One example cited from a study by Howard University in Washington, D.C., was an estimate of final penetration of 40 percent with a subscriber fee of $10 and a final penetration of 70 percent with a subscriber fee of $5. The temptation to seek rate increases in the early years should be resisted, as such increases would slow the growth and the eventual penetration.

When cable systems are installed in urban centers, service provided should serve all residents of the city: the municpal government, schools, businesses and households. Such services, especially ones involving point-to-point, would quickly fill up a single cable, or even two cables. Therefore, point-to-point cable networks should be overlaid in a grid-like fashion on the conventional cable distribution plant with interconnection capability. Such point-to-point cable grids can be installed at low incremental cost at the same time as the conventional system; the electronics can be installed at a later date as the application becomes definite.

Cost support of programming for multiple channels should come from the revenue of operating the system. Approximately, one-fourth of the total revenue should be ploughed back for programming purposes.

Question: Is the point-to-point network competitive with the Telephone Company?

Answer: Yes, in a limited way. Interconnection among systems, as presently planned is by a manual patch which doesn't lend itself to random interconnection of large numbers of subscribers.

Question: If cable were used to relay sensing and control of large power grids, what advantage does that have over clock timed systems?

Answer: The times peak loads occur are not entirely predictable.

Question: With the sophisticated technology available in cable systems, what protection does the average person have against have against cable acting as big brother?

Answer: You have to pay for security. The most secure method of transmission is cryptography, which is also the most expensive. In the larger view, cable appears to offer more services at reduced price to the average person, and big brotherism is not expected to be a factor.

3. "What Belongs on the Cable" - John Ward

There is a danger that the public will be oversold on the applications and services of cable television. It is important to recognize:

What services are beneficial and practical for cable?

What services are not practical for cable?

After determining these answers, find out what services will be accepted and used by the public.

The bandwidth capacity of cable television is 300 MHz as compared to 4 KHz for a telephone line into the home, a bandwidth ratio of 75,000 to 1. However, this is deceptive in that frequency multiplexing is complicated and has its limitations.

In the tree configeration of a cable network, the trunk is the bottleneck. Given this limitation, the services provided should be for the public at large.

Separate point-to-point networks should be established for special purposes.

Cable should be thought of as a gigantic party line. A single 4 MHz channel can drive 4000 teleprinters simutaneously. The TICCIT system of addressed frame video can transmit 216,000 different picture frames per hour.

A tree structured cable system is insufficient to support large numbers of two-way video conversations. For that, a switched, hub structured cable plant would be needed. However, the tree structure permits the placing of all subscribers on one or more large, broadband party lines on which addressed, time-division-multiplex messages can be transmitted at very high rates. This clearly represents a new dimension in communications capability. The main problem is: What services can be made to pay for themselves?

To determine the economic viability and the audience acceptance, two-way systems and interactive services may have to be subsidized. Large scale experiments, conducted for a substantial period of time will be necessary to shed some light on these different questions.

4. "Blue Sky To Cash Flow - Market Study" - Robert Behringer

In studying the economics of cable television, our approach was to reduce complex systems to basic parameters leading toward valid predictions of cash flow.

The interface with the ultimate consumer is where the market is conclusively established. This means an interactive home terminal for the broadband communications network. This is the crucial link for the subscriber to participate in the programming and services offered in the next decade.

In the last 70 years, we have consistantly underestimated the growth potential of major industires. The same could happen to cable television. The cable network with interactive home terminals will bring essentially the same services and information to the subscriber that he now has available but faster and in a more convenient way.

There is only one way to properly evaluate the market potential, which is what Theta-Com is doing in El Segundo, California - install a broadband communications system, or convert an existing system to two-way operation; install the interactive home terminals on a complete saturation basis; furnish as many good services as you can and market them; analyze and project the results to cover other markets.

In extrapolating this test data, be aware that the process of changing behavior is gradual. Habits of a lifetime will not be quickly changed.

Services, entertainment and marketing should be handled by a separate organization rather than the company operating the cable. The reason for this is the specialized nature of the marketing effort required.

Question: If a set-top converter is necessary, will the cable company supply it?

Answer: It will be supplied as part of the monthly rental. As with the Telephone Company, you don't buy the instrument; you buy the services.

Converters will eventually be built into receivers, though, because there are approximately 70 million existing receivers. Replacements with converters will not reach significant members for many years.

Question: Remote shopping sounds optimistic. Is the television resolution and color adequate? Isn't self-service in stores a growing trend?

Answer: Most television shows have advertisers who apparently believe that their products are sold by the commercials. In fact, in selling by cable, there is a hazard of too much impulse buying because the mechanics of the purchase will be so easy.

Question: If the only way to get past the test phase is for a company to take a gamble on a large investment, are there such companies willing to take the gamble?

Answer: I know of at least six such companies.

Question: If revenue comes to the company who is selling a product by using cable television, shouldn't the subscriber fee be reduced accordingly?

Answer: Probably so, eventually. It should be realized that the new skills and systems that must be established in stores which sell by cable will be extensive and will be costly to the stores in the start-up phase.

COMMUNICATIONS FOR IMPROVED QUALITY OF LIFE

Dr. Peter C. Goldmark
Goldmark Communications Corp.
Stamford, Connecticut

Early in 1970, the Department of Housing and Urban Development, the Federal Communications Commission, the Department of Transportation and the Departments of Commerce and Justice joined to fund a study at the National Academy of Engineering to explore the applications of Communications Technology for improved urban functions and for the creation of a better rural life.

The Academy's Committee on Telecommunications entrusted this task to the Panel on Urban Communications which I chaired.

We have separated our tasks into a number of subpanels: telecommunications applied to Administration and Emergency Services - to Crime Prevention - to Education, Recreation and Cultural Pursuits - to Environmental Factors, and finally a program called "The Cities of the Future". The members, advisors and resource persons serving on our panel, represented the country's top talent in the field of Communications Technology. The fruits of our labors are contained in the National Academy of Engineering's special report of June, 1971 in which we proposed some 19 pilot projects for our federal sponsors.

One of these proposals, based on our Panel's "Cities of the Future" study, is now sponsored by the Department of Housing and Urban Development under contract to Fairfield University. The project, called " The New Rural Society", is now in its third month of operation.

Our study is founded on the thesis that within the last century and a half, science and technology have unwittingly caused an ever increasing rate of change in all aspects of our lives, including growth of population and the depletion of our environmental resources. There is a steadily growing crisis, originating in our tightly packed metropolitan centers, where 80% of our population live on less than 10% of our land. Thus the problems of the large city are the problems of the nation and the continuing increase of crime and pollution together with the social, health and educational problems inexorably tend to move us towards a catastrophic collapse. The irreversible exhaustion of our environmental resources, which include some of our minerals, fossil fuel, waters, animal life, etc. is closely linked with the stark imbalance of the population distribution. When adding the resultant stress and strain in human life, it becomes essential that science and technology embark immediately on the task of improving significantly the quality of life and to do this within the shortest possible time.

The New Rural Society calls for giving Americans a choice whether to live and work in an urban or in a country environment. As of now such an option is not available and our plan must make it attractive for 100 million Americans in the next 25 years to remain in or move to rural areas. The so-called "new towns" will not accomplish this. They tend to be built too close to metropolitan centers - besides, to absorb 100 million people by the end of this century, a new town would have to be completed every third day.

We have designed a model based on 3,000 existing communities ranging in population from 5,000 to 100,000 people where imaginative planning and a controlled rate of growth could create superior living conditions for about one third of the U.S. population. In order for the plan to succeed, we must provide in these 3,000 communities adequate employment, better educational and health services, and in particular social, cultural and entertainment opportunities.

In each of these areas we have found that Communications Technology, imaginatively applied, can make a decisive contribution. Thus, one part of our study deals with business communication systems to induce companies to decentralize their operations into truly rural towns rather than into suburbs. The objective is to eliminate commuting and make it possible for the majority of Americans to walk or bicycle to work.

Our study also concerns itself with the application of Communications Technology towards improved health care and education in rural America. Today, I would like to elaborate on the cultural and recreational needs of the New Rural Society.

Today our largest metropolitan centers offer many cultural and entertainment opportunities, which are available to only a few but could become a crucial requirement for many, if we as a nation are to establish a more uniform distribution of population.

We have the technology to design communication systems so that the citizens of the New Rural Society can see and hear plays, operas, concerts, museum tours, lectures presently available to the relatively small and select audiences in the large urban centers. Several of the communication satellite systems now propsed to the Federal Communications Commission, will be capable of broadcasting to ground receiving installations live programs from Broadway, the Metropolitan Opera, Philharmonic Hall, museums, etc.

Many hundred or even thousands of receiving ground terminals can be provided near the towns, which will grow to become part of the new rural development plan.

These live event programs together with over-the-air TV broadcasts and special cable TV originations could provide hundreds of millions of Americans with an enormous choice of entertainment and cultural enrichment, heretofore unattainable. In order to provide this service for the New Rural Society, a well planned national cable TV system of the highest capacity and technical performance is essential. Fortunately, all this is becoming a reality, but what is still missing, are the satellite communication links which will deliver to every town and every cable TV system in America all the important art, entertainment and cultural offerings of the nation.

Under the New Rural Society plan the majority of the 3,000 or so communities which are to attract people from the large urban centers, would have large TV projection screens installed in existing and new theaters, thereby creating a cultural and entertainment center for the community. Most of the live performances will take place in theaters, operas, auditoriums, etc. where the current commercial TV standards would no longer give satisfactory rendition. Also, the presentation on large theater screens will make it necessary to introduce new high resolution color TV standards suitable for this new service. The improved color TV standards would go beyond the European 625 line service and be suitable also for transmission over the new cable TV systems. It is the intention of our organization to develop such a system and to work with receiver manufacturers towards creating new dual standard color receivers specially adapted to the cable service. It is logical to assume that in a given community it will be the cable TV operator who will also make the high resolution satellite transmission available both for large screen projection in theaters and for the cable TV subscribers.

CATV'S CRITICAL MASS PROBLEM

J. J. O'Neill
The MITRE Corporation
McLean, Virginia

PROMISES AND PERILS

The introduction of cable systems into the nation's urban centers presents almost equal measures of promise and peril to potential builders of such systems. The opportunities and needs of urban centers present a direct and welcomed challenge to cable system advocates almost everywhere. Communications, in general, and cable, in particular, have long been heralded as the means toward such broad and laudable goals as better understanding among citizens and improved urban living. The magic of words like "interactive" and "two-way" simply quickens the excitement; almost by their very mention alone.

However, businessmen and bankers quickly note fundamentals.

(1) Urban dwellers already have an abundance of clear TV pictures. In addition, they may have a significant number of attractive cultural and entertainment alternatives readily available.

(2) No one has identified an aggregated set of services that will insure adequate system penetration.

(3) A basic cable distribution plant must be laid in each major urban center and this represents a major initial capital expenditure. The need for set-top converters in virtually every urban household does nothing but increase this expenditure.

The degree of peril is clearly indicated by the interest rates currently charged for borrowed capital.[1]

Financially the cable industry has evolved much as the telephone industry; that is, subscriber fees have formed the financial structure. If one assumes the cable industry is more like the broadcasting industry - that is, advertising revenues instead of subscriber fees will eventually support the capital structure - it is clear that almost total penetration will become mandatory. What advertiser wants to talk to less than 50% of an urban market when he can reach an entire region via radio or TV broadcasting or newspapers?

In either case the key to cable may be simply stated by one word - SUBSCRIBERS and the goal line is clearly marked - SATURATION.

PLANNING CRITERION

Starting with the positive premise that cable will eventually be as ubiquitous as the telephone and the electric, gas and water utilities, and that the benefits of total penetration are desirable, one criterion might be applied to all system planning decisions; viz, "MAKE THE DECISION THAT WILL ACCELERATE THE SUBSCRIBER GROWTH RATE WHILE STILL GUARANTEEING ECONOMIC VIABILITY".

This "motherhood" criterion may appear to be obvious; its application may not be. The following are examples of this criterion applied to a few of the basic system parameters of urban cable systems.

PENETRATION

In rural areas where over-the-air TV reception is poor and nearby cultural and entertainment opportunities are nil, it has been said that monthly subscriber fees anywhere in the range of $3 to $8 will result in about the same number of subscribers. Over the last few months articles, apparently based on this premise, have been advising operators not to be timid about requesting rate increases. This advice may not apply in urban areas where people have many alternatives to cable--such as a pair of rabbit ears.

One particular urban survey was specifically designed to determine the incremental demand for different types of services and programming as a function of the subscriber fees charged. It was conducted by Howard University in Washington, D.C. for The MITRE Corporation. The results were applied to a cable system design for Washington, D.C.[2] Figure 1 shows the main results of the Howard survey; namely, the final penetration is very much a function of the monthly subscriber fee charged. As the fee is lowered, more subscribers come on board; regardless of the sophistication of the services being provided.

Time could be spent arguing the absolute value of the final penetration, the most desirable service or group of services, or the slope of the curves. But one thing is clear, the curves have slopes. The only place the curves level off is when subscriber fees are so high that no one subscribes and zero penetration is obtained.

Figures 2 and 3 display this data in terms of total system revenue for various combinations of subscriber fees and penetration. The cost of building and operating the system is overlaid on the revenue data. It can be seen that the profits, or the difference

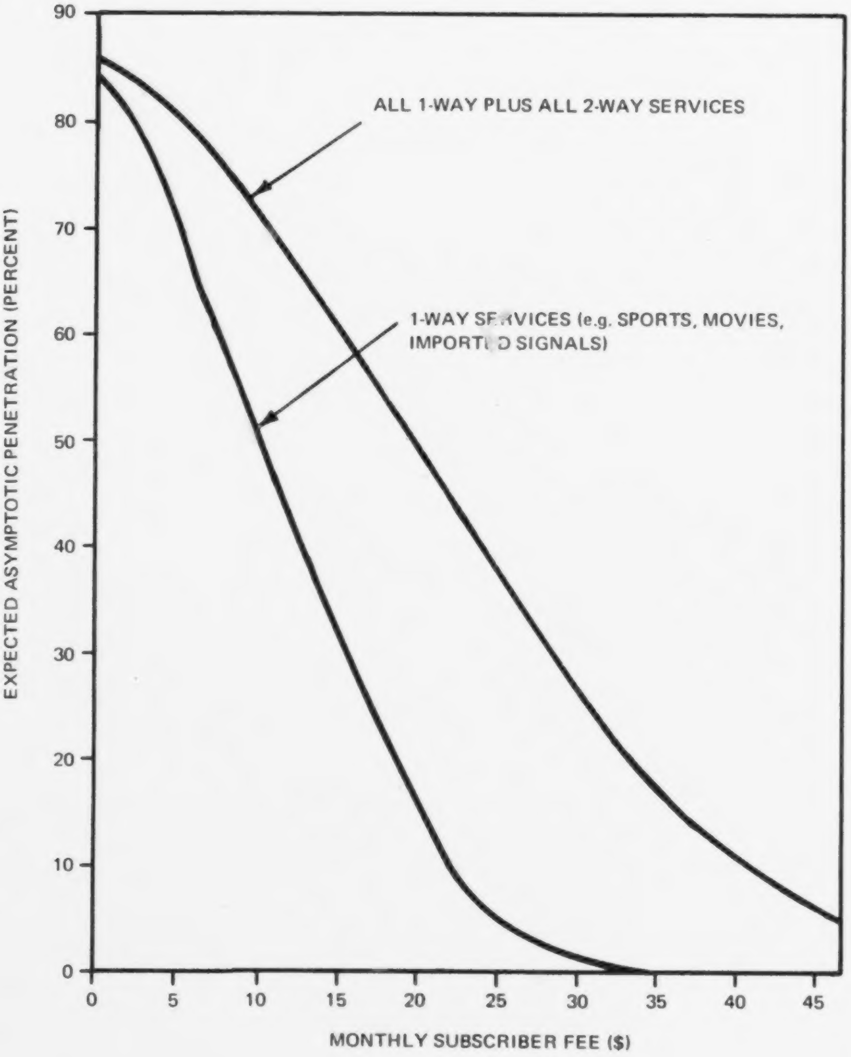


FIGURE I

RELATIONSHIP OF EXPECTED FINAL PENETRATION TO MONTHLY SUBSCRIBER FEE FOR TWO COMBINATIONS OF SERVICES

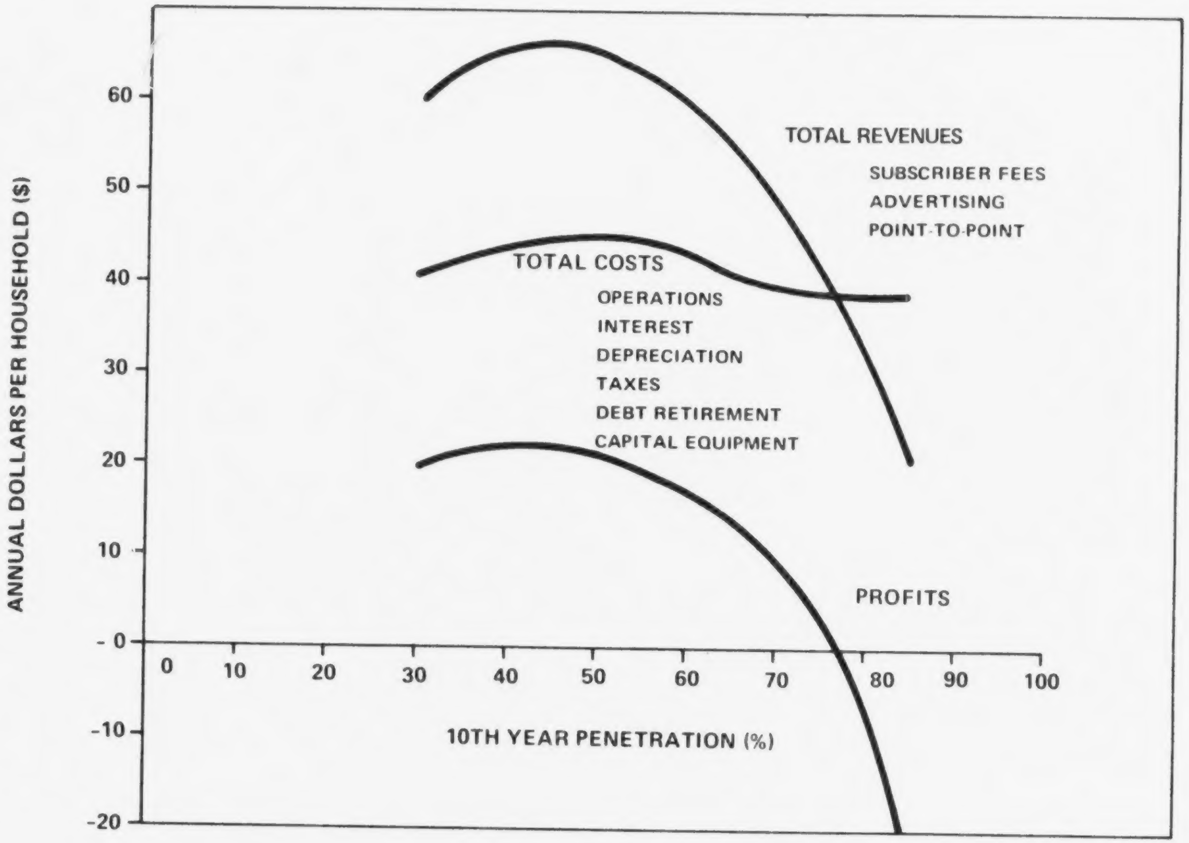


FIGURE 2

PENETRATION VERSUS ANNUAL DOLLARS PER HOUSEHOLD
FOR ONE - WAY SYSTEM

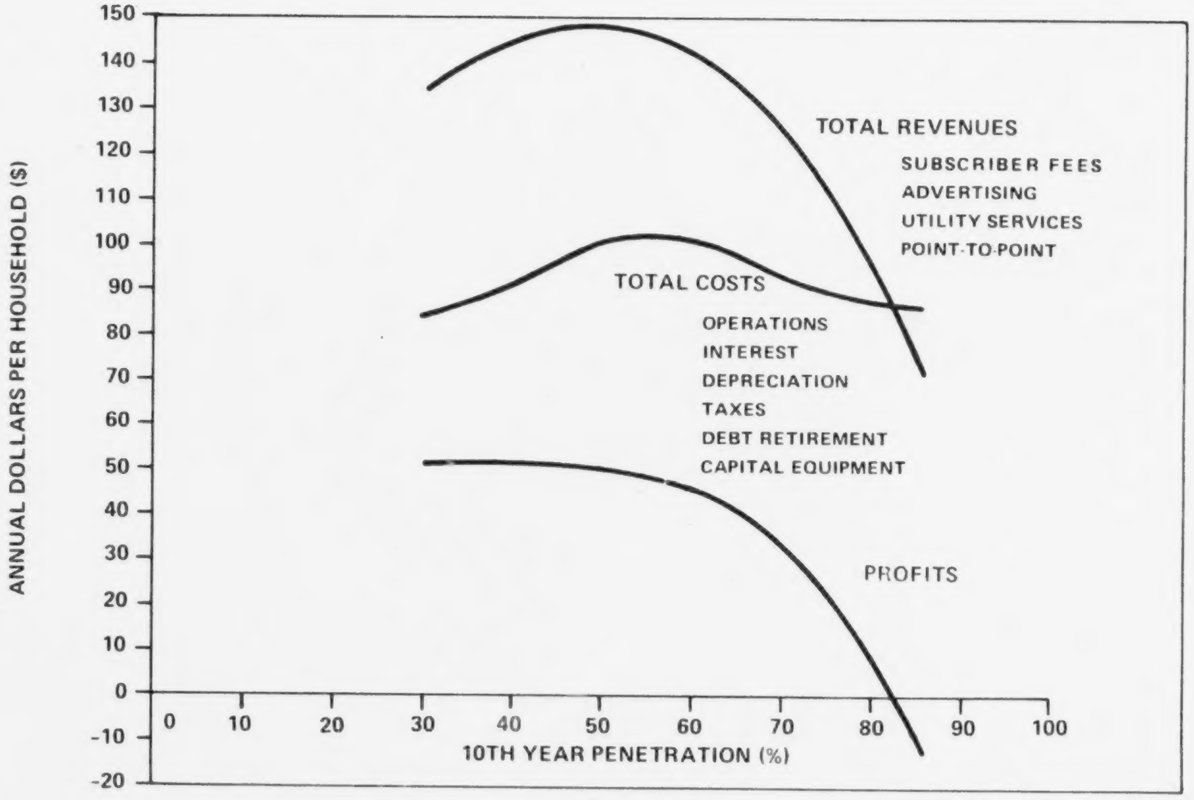


FIGURE 3
PENETRATION VS ANNUAL DOLLARS PER HOUSEHOLD
FOR TWO-WAY SYSTEM

between revenues and cost, peak in the region of 50% penetration and at a monthly subscriber fee of approximately $8.

Now comes the dilemma and the decision!

Which is more important to management, higher surpluses or higher penetrations? Or more basically, will a monthly fee of $3.50 be charged in an attempt to obtain a penetration of 70% or more - or $8.00 in an attempt to maximize near term profits?

The main criterion opts for maximizing system penetration.

REQUESTING RATE INCREASES

During the early years of system implementation there is another tempting mechanism available to cable system operators to increase revenues. Figure 4 shows rate-of-return on equity in each year of system operation, assuming a 2:1 debt-to-equity ratio. This annual rate-of-return assumes the final value of the system to be seven times the annual revenue, plus cash-on-hand, minus outstanding debt. The peak in the rate-of-return is partly caused by tax carry-over provisions. The early years of no positive rate-of-return illustrates that cable needs plenty of capital while it is being built with little hope of financial return.

The temptation to seek rate increases from city councils in these early years, while losses can be documented, should be resisted. Again, because such a rate increase would only slow both the subscriber growth rate and the final penetration.

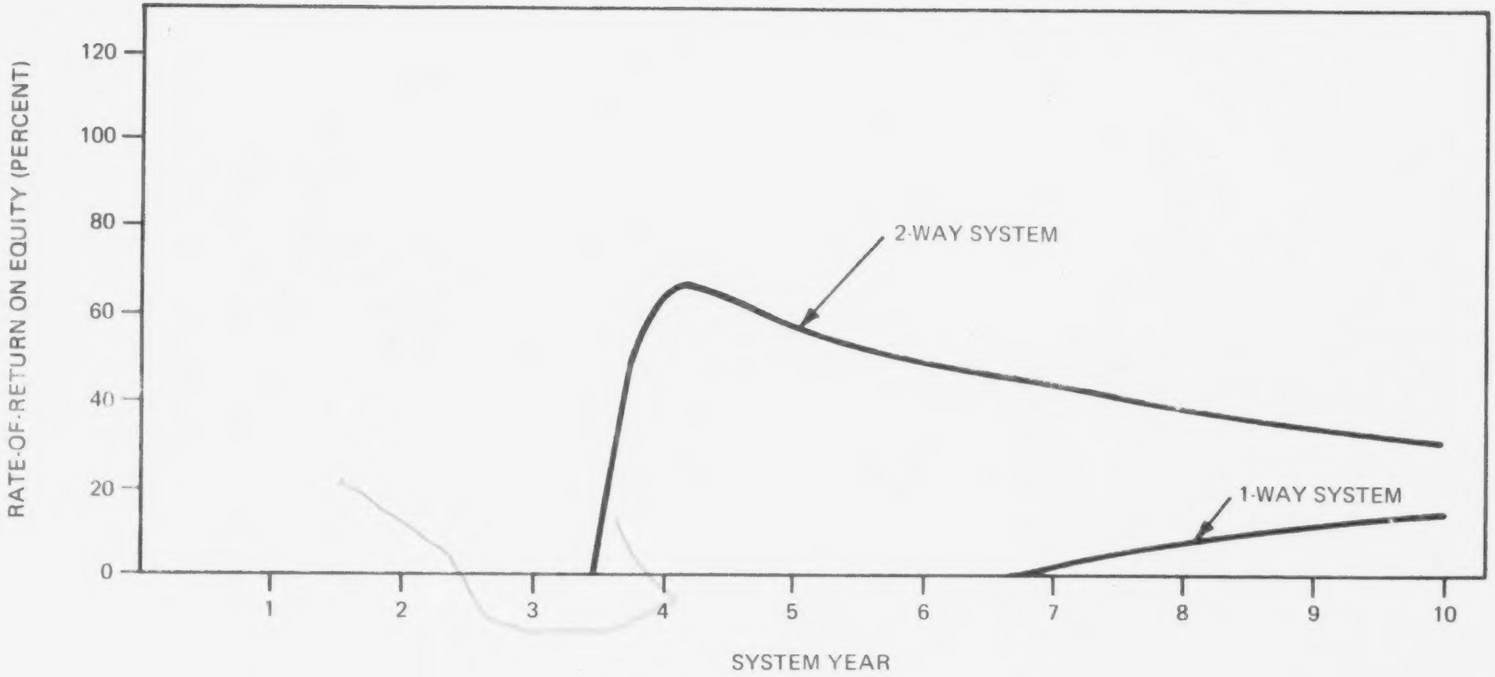


FIGURE 4

COMPARISON OF INTERNAL RATE OF RETURN ON EQUITY

AGGREGATED CLIENTELE

When cable enters the nation's urban centers it should direct its capability for services toward all the residents of the city - to the municipal government, to the public and private schools, to the colleges and universities and to the business and commerce community, as well as to the "household communities".

The FCC Rules and Regulations[3] include a requirement for a municipal channel, and an education channel. Why not a cable-full-of-channels for each? Why not separate point-to-point cable nets overlaid in a grid-like fashion on the conventional cable distribution plant; one each for the municipal government, the educational institutions and major business concerns? Table I shows key characteristics of such nets for Washington, D.C. and the costs are included as part of the total system costs plotted in Figures 2 and 3.

Selective Power Control is being used by Detroit Edison to help alleviate brownout and blackout problems. There, 200,000 dual element water heaters, representing 360 MW of power, are radio controlled. During short peak load periods one element of these heaters is selectively turned off. Thus, up to 360 MW of power, costing $77M of standby plant equipment, does not have to be generated. The radio control system costs $9.6M. Part of the savings are passed on as lower yearly utility rates (and subscriber fees?). Cable systems could easily provide the communication link for this type of service. Iron lungs, elevators and hospitals could be given a higher assurance

TABLE I
POINT-TO-POINT NETS

TYPE	NUMBER OF SUBS.	LENGTH (MILES)
FEDERAL CAPITOL BUILDING AND MAJOR FEDERAL BUILDINGS $417,000 30 CHANNEL PAIRS	54	10
MUNICIPAL SCHOOLS, FIRE, POLICE, HOSPITALS, SANITATION, ETC. $807,000 14 CHANNEL PAIRS	271	73
INSTITUTIONAL BANKS, DEPARTMENT STORES $952,000 14 CHANNEL PAIRS	300 to 3000	50
HIGHER EDUCATION ALL PUBLIC AND PRIVATE FACILITIES $183,000 14 CHANNEL PAIRS	23	15

of continuous operation at the expense of air conditioners, washing machines and dryers.

Why not promote Selective Power Control as a national cable service? It does not require high initial penetrations as does utility meter reading and it certainly provides an incentive; that is, extra revenue for the system.

Washington, D.C.,[4] New York City,[5] Charleston[6] and San Jose[7] are experimenting with traffic control systems. Cable can provide the communication links for such services and save the city money.

The local distribution of specialized common carrier data may be another near-term service that cable can provide to its non-household customer.[8]

Cable systems should tap these non-household markets and include the entire city and its many functions as its clientele. Only in this way can cable be in a position to provide the broad spectrum of services promised. The economic arguments for multiple cables being drawn when the conventional plant is initially installed can be persuasive indeed.

Let me digress for a moment. When I moved into my home recently I found three built-in telephone outlets with seven twisted pairs behind each. Opportunities for twenty-one revenue producing services per household were being provided and I had not even spoken to the telephone company. There is a message there--for all of us.

COMMUNITY PARTICIPATION

Programming sources to supply this industry that continues to provide more and more channels can become a serious near-term problem. Local community studios, easily accessible and moderately equipped must be provided if a community voice (and a new program source) is to be realized. The FCC's[3] community access channel requirements and their additional requirement for one non-broadcast channel for each broadcast channel will insure programming the status of a long term issue.

Commissioner Johnson suggests[10] that portions of a relatively high franchise fee be reserved by cities through an independent commission or by private groups with grants from the city for the purpose of cablecasting programming. This idea sets up a middleman to handle the funds and decide on the type of programming. The handling fees of such collection commissions are well known.

The expense curves of Figures 2 and 3 include approximately one-fourth of the total yearly subscriber's fee being ploughed back yearly for programming purposes in both the one-way system configuration and in the two-way subscriber response system configuration. Over a ten year period this amounts to $15M being allocated to programming in the one-way system configuration and $34M in the two-way system configuration. In addition, it provides nine local studios moderately equipped costing a total of $500,000.

The economic analysis of an urban cable system requires many different assumptions and the sensitivity of these assumptions must be tested. For the Washington, D.C. system,[2] the economic analysis was repeated using various values for key parameters such as those shown in Table II.

SUMMARY

Again, these are just a few thoughts directed toward the peril side of cable's promise. They represent some changes in the conventional approaches directed toward obtaining the critical mass of subscribers necessary for both economic and social viability of urban cable systems.

ACKNOWLEDGEMENT

Many of the thoughts and much of the background information for this report were developed during the course of a study of the economic viability and technical feasibility of urban cable systems which was funded by The John and Mary R. Markle Foundation; Reference 2 is the final report of this study. I wish to acknowledge the contributions of other key members of the study team, Frank R. Eldridge, William F. Mason, Carol A. Paquette, Friend L. Skinner, and Ralph L. Smith.

TABLE II
SENSITIVITY ANALYSES

- RATE-OF-RETURN
    - D/E
    - INTEREST
    - MARKET VALUE
- SYSTEM PENETRATION
    - FINAL VALUE
    - GROWTH RATE
- CAPITAL COSTS
- SYSTEM MAINTENANCE
- ECONOMIES OF SCALE
    - STUDIO COSTS
    - PROGRAMMING COSTS
    - OPERATING COSTS
- MULTIPLE FRANCHISES

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2. Urban Cable Systems, The MITRE Corporation, Washington Operations, April 1972, Section V, Demand Analyses.

3. Federal Communications Commission, Cable Television Service; Cable Television Relay Service, Part II, Vol. 37, Number 30, Federal Register, February 12, 1972.

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5. Friedlander, Gordon D., "Computer Controlled Vehicular Traffic," *IEEE Spectrum*, February 1969.

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8. Letter to Mr. F. Eldridge, MITRE Corporation, from Mr. Delmer C. Ports, Engineering Director, NCTA, 27 May 1971.

9. Specialized Common Carriers, Telephone Engineering and Management, October 15, 1971, page 41.

10. Cable Television: The Future as History, Commissioner Nicholas Johnson, FCC, 10 March 1972, Ohio Cable Television Association presentation.

WHAT BELONGS ON THE CABLE

John E. Ward*

Many papers and articles over the past two or three years have suggested that the 300-MHz coaxial CATV cable carries sufficient bandwidth into(and out of) the home that it can serve almost every conceivable home communications need--providing as many TV viewing channels as anyone can think of a use for; two-way data, audio, and data services, and perhaps eventually taking over the functions of the present voice telephone system and augmenting it to provide full nationwide videophone service with TV bandwidth. At the same time, the cable is touted as the way to also provide data and facsimile services between businesses, video and audio interconnections between schools (and school systems), and a wide variety of municipal communications services such as police and fire networks, traffic surveillance and control, and so forth. The purpose of this paper is to examine some of the realities of this communications utopia from the standpoints of performance and cost, suggest those areas where the cable seems best suited to providing new or improved communication functions, and just as important, point out those areas where the urge to "cable-ize" may be inappropriate.

First of all, let's talk about cable capacity. It is true that the 300-MHz bandwidth of a single coaxial cable, or the 600-MHz bandwidth of two cables, can theoretically carry about as many entertainment, education, or citizen-information viewing channels into the home as anyone would probably ever want. As is well known, there are a number of complicated technical problems in trying to use every scrap of the available cable bandwidth, but these do seem to not represent a serious limitation at present, and should gradually be solved in the future as cable technology improves. The present cost increment for just increasing downstream capacity per cable to 25-30 channels is not great, but cable system costs (including frequency multiplex/demultiplex equipment) can rise quite steeply if many additional signals of various types are to be carried;

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*Deputy Director, Electronic Systems Lab., M.I.T.

i.e., the solution to the technical problems of adding these signals without mutual interference may be quite expensive in terms of system cost.

It is also true that through use of presently available time-division-multiplex (TDM) techniques, just a few channels used for two-way digital data services, plus possibly addressed-frame video (sometimes called "frame grabbing), can provide individualized communications services of enormous capacity for all subscribers in a system. A single one-megabit, two-way data channel (which requires no more than 4 MHz downstream and 4 MHz upstream) can,for example, drive about 4,000 printers simultaneously at 10 characters per second, at the same time accepting the same simultaneous input rate from 4,000 keyboards or other data input devices. Since every home obviously won't be receiving or sending all the time at this rate, such a data channel should easily serve 20,000-30,000 homes (or more, depending on how much access delay is permissible), each of which can also be polled at least every few seconds to see if they wish to initiate communications. If in addition, just one downstream TV channel is devoted to addressed-frame video, as many as 216,000 different text or picture frames per hour can also be transmitted, surely sufficient for the on-demand information access needs of our 20,000-30,000 homes.* These individualized services, however, do carry a high incremental capital cost for the necessary home terminal equipment. Added head-end equipment costs are nominal on a per-subscriber basis, except as the services become more sophisticated. More will be said about this later.

Where the seemingly bountiful cable capacity begins to look less bountiful is when one adds requirements for any significant number of non-TDM, dedicated, upstream or downstream TV-bandwidth channels that are for "private" use of some sort, and not for general viewing. For example, 4-15 TV channels per trunk seems a reasonable range of upstream capacity, depending upon whether one has a one- or two-cable system (this assumes that in a two-cable system about half of one cable would be used for upstream signals). Allowing a few of these upstream channels for remote program origination use, a few each for school and municipal TV interconnections (note that these interconnections would probably be two-way and thus also need a downstream channel per upstream channel), there isn't room left for very many traffic or security surveillance camera channels (for example), or for much private TV channel usage by individual subscribers.

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*See for example "The Reston, Virginia, Test of the Mitre Corporation's Interactive Television System, John Volk, Report MTP-352, Mitre Corp., May, 1971. This system digitally addresses each interlace field separately and thus transmits 60 262-line images per second, each containing up to 800 alphanumeric characters.

Carrying this last point to the extreme, the total upstream and downstream channel capacity of a tree-structured cable system is clearly insufficient to support large numbers of simultaneous, individual, two-way video conversations (i.e., videophone service). For that, a switched hub-structured cable plant (with individual subscriber lines) would be needed, organized like the telephone system. This is the cable configuration of the Rediffusion, Inc., "Dial-a-Program" CATV system,* and may certainly be cited as a potentially great advantage of that system. However, their present one-of-36 program-distribution switchgear was not designed for line-to-line switching and would have to be very greatly reorganized and augmented in order to provide the switching functions needed for many simultaneous subscriber-to-subscriber two-way connections on a dial-up basis. The cost of such switchgear would be very substantial.

Returning to the tree-structured cable, it is interesting to speculate what would have happened if cable systems of this type had been invented 100 years ago and installed before any other type of communication system. I am sure that the bottleneck represented by the finite simultaneous cable channel capacity per trunk would eventually have forced many full-time users (or potential users) off the cable and onto circuits dedicated for their own use, and many other users desiring part-time, private circuits onto a switched network of some sort. Thus, one must certainly closely examine potential "non-broadcast" cable communications functions or services that cannot be time-division multiplexed on just a few channels (in the manner discussed earlier) to see if it is technically practical (or economic) to devote the necessary cable bandwidth continuously to their needs, as opposed to services available to all subscribers. In many cases, dedicated facilities may represent a better solution for users with heavy communication needs between just a few locations--for example, if closed-circuit, inter-classroom usage between all schools in a city requires more than one full-time two-way channel, a private inter-school cable may be advisable, in addition to CATV cable tie-ins for its program and general communication services. Of course, if a given cable system does have unused operable channels, adding such functions or services up to capacity makes sense, at least for the short-term. The intent of this discourse is not to say that such services don't belong on the cable, but to point out that there are limitations in total capacity, and that the various "closed-circuit" services that one hears discussed can't all be handled without going to special cable configurations for this purpose. The question then arises as to whether these special, dedicated cable facilities should be handled by a CATV operator, or in some cases, even be interconnected with a CATV system at all.

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*"Dial-a-Program--an HF Remote-Selection Cable Television System", R.P. Gabriel, Proceedings of the IEEE, July, 1970, pp. 1016-1023.

On the other hand, it is worth re-emphasizing that the cable does have a unique, very practical capability for providing, at little cost in bandwidth, a class of communications services that can only be awkwardly handled (if at all) by existing communication systems--the simultaneous, rapid, two-way interaction between a very large number of individual subscribers and a central information processor/source. The key concept here is that the network configuration of a cable system permits the placing of all subscribers on one or more gigantic, broadband party lines on which addressed, time-division-multiplex, messages can be transmitted at very high rates. This clearly represents a new dimension in communications capability, and one which has great potential as an addition to other cable services. The main problem is: What sorts of services can be made to pay for themselves, given the high costs of the necessary terminal equipment for home and possibly business uses (and for certain services, of the associated head-end equipment and/or interconnections with other data bank systems)?

I am afraid that I have no ready answer to this question, but it may be of value to cite the factors which must be considered. First of all, I see this as a "chicken or the egg" situation. The economics of two-way communication has a serious critical mass problem, both in the number of subscribers equipped and connected for a given polling-type service (say meter reading), and also in the number of access services (banking, shopping, etc.) available to a given subscriber. (As an AT&T official was recently quoted in relation to the decision to temporarily shelve Picturephone, "It's no good if there is no one else to talk to.")* Thus two-way hook-ups and services may have to be subsidized in some way to ever get off the ground and their eventual self-supporting viability would seem to depend on the totality of a large number of different services each with modest fees, rather than a few services with high fees (a possible exception is pay TV).

Second, there is still a large human factors question in regard to the sorts of services under discussion, which are generally new services never before available. Given that a broad spectrum of possible services is set up and offered to subscribers in their "electronic fortresses", will they use them to the extent necessary for economic viability of the services? For example, even if a service such as home shopping is immensely popular as a concept, would enough subscribers pay a monthly terminal fee for the service, plus possibly a price premium on purchases due to the added sales costs for goods presentation on camera, automated order taking, and home delivery after purchase? Large-scale experiments, conducted for a substantial period of time (sufficient for novelty transients to die out), seem the only way to really shed some light on these difficult questions, and will require extensive cooperation and commitment on the part of many organizations for a given experiment.

A brief word about head-end costs for new types of individualized services. Simple polling and data store-and-forward interconnections with other computerized data services (banks, stores, reservation systems, etc.) can be handled by a small computer with a capital cost of only a few tens of dollars per subscriber. Similarly, the head-end could forward subscriber requests for addressed-frame video signals originating elsewhere (say in a library) and put the signals on the cable at little cost in head-end equipment. However, if the cable operator wishes to provide digital data bank, data processing, or video frame services himself, his head-end costs could go up by an order of magnitude or more, depending on the services provided (rapid-access memory devices of all types tend to be very expensive). Only time and experience will show how some of these services can best be provided (assuming that there is a real market for them).

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*"Picturephones Shelved Due to Lack of Demand", The Washington Post, April 13, 1972.

This discussion has been deliberately couched in rather general terms, without attempting to predict costs for this and that out to the penny for some future period. Many such predictions are available, and the author has previously made some of his own.* What seemed more valuable for the present purposes was an exposition, from a communications systems viewpoint, of what types of services the cable seems best at, and of what other services it could provide, but with performance difficulties or at high cost. It is hoped that this has proved useful.

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*Appendix A, "On the Cable--The Television of Abundance", Sloan Commission on Cable Communication, McGraw-Hill Book Co., December, 1971.

BLUE SKY TO CASH FLOW - MARKET STUDY

Robert W. Behringer
Theta-Com Corporation

After rereading the synopsis of the content of this session, I'm a little uncertain as to whether or not the task can be properly accomplished at this time. The title "Blue Sky to Cash Flow" implies a wide range of developing technologies and techniques for the CATV industry. These include the use of satellites, interconnection of cable systems, new social services, data retrieval, digital, microwave or laser transmission of CATV programming and expanded communications bandwidth, among others. In almost all cases, the so-called "Blue Sky" can be brought down to the bottom line, to cash flow, only by use of a broadband communications network incorporating some form of interaction with the individuals comprising the population.

In this discussion, I will restrict myself to the interface with the ultimate consumer since this is where the market is conclusively established. This means an interactive home terminal for the broadband communications network and is the crucial link for the subscriber to participate in the programming and services offered in the next decade. The synopsis went through a brief general discussion of the topic, and then wound up with the real nut "reducing complex systems to basic parameters leading toward valid predictions of potential cash flow." That is what is needed to make the decision of whether or not to install interactive home terminals and which services to offer if and when these terminals are installed. How should we study the market?

I think a good way to put this in perspective is to ask ourselves a question: What if Henry Ford had a management consulting firm make a market study on horseless carriages? The answer, I believe, is obvious, based on my having participated in some studies of this type. An expert would have sent out a questionnaire to a lot of horse and buggy owners; he would have assembled statistics; he would have conducted personal interviews; he would have made an economic and technical model, and would have come up with the "obvious" answer. The horse and carriage is here to stay and the horseless carriage is a toy that only the very wealthy can afford.

Now there just might have been someone in that firm with a gut feeling who would guess the future and predict the right answer. I don't think so, however. If he had even dared to predict that these "toys" would someday outnumber horses, he would have seemed foolish.

Today we can look back and see how major industries have developed in the past 70 years. In almost every case of a major social or commercial need in this country, we have consistently grossly underestimated the potential; i.e., telephone, electric power, computer use, office copiers, color television, etc.

Today we are faced with a situation similar to the horseless carriage manufacturer. We have a product – interactive home services – which can economically and conveniently supply services that are already in existence and being taken care of by a variety of other means. As an example, we can supply to the subscriber a device which will store one frame of video information, a "frame grabber" with semi-random accesss to a large data bank. He now satisfies this requirement with libraries, magazines, reference works at home, newspapers, telephone calls, etc. The frame grabber, however, will do this more quickly and conveniently. We are now attempting to make a market study to determine how many such services people will be eager to accept. How will people want to use a broadband communications system with interactive capabilities?

At this point, I think it appropriate to bring another factor into the analysis. In the last 20 years, the big change in buying habits has been to convenience items, such as frozen or prepared foods, automatic kitchen appliances, etc. We reach the conclusion that the Broadband Communications Network with interactive home terminals will bring essentially the same services and information to the subscriber that he now has available, but in a faster time frame and in a more convenient way. He might also avail himself of more services than he now uses, because of the convenience of using interactive home terminals.

We could spend many hours examining this issue in detail; however, one example would suffice. When you go to a department store, the first thing you usually do is to get into an automobile and drive to the department store location. This takes an automobile, gasoline, and a lot of frustration. When you finally get to the store, you have the problem of finding a space and parking so as not to have the car damaged by others. You enter the store and try to find a clerk. They are usually quite independent people and very elusive. Now you have him, and you tell him what you want to buy. They may or may not have the exact item you wish to purchase in inventory. It may take 10 or 15 minutes to find it or to determine if they are out of stock. If they are you must go to another store. If they have the item, he checks your credit card usually by telephone. Finally, he rings up the ticket and then you must retrace your weary steps home. This entire process may have involved 2 to 4 hours of your time.

The purchase might have been accomplished by phone; however, the buyer usually likes to see and feel what he is buying even if he could shop by phone. The interactive home terminal should be successful for shopping services if we can convince the consumer that it is not necessary to feel the item. Although some consumer behavior must be modified, the greater convenience will sell the service. What I'm moving towards is how you can approach making a market study for the services that a Broadband Communications Network utilizing interactive home terminals can offer.

If you note the costs of all the services that people buy or participate in, you might say that the costs could, in the limit, transfer as gross revenue to the company operating the broadband communications network and interactive home terminals. This would be the height of optimism and could result in disaster. To start with, personal habits in obtaining the services and information are going to have to be modified. This means a slow buildup in volume. Secondly, the services and information provided will need to be less costly. And lastly, the convenience must make it attractive.

This brings to mind an example of how wrong a paper market study can be. Some years ago I worked on a program of cold sterilization using electron beams or nuclear by-products. Among the many things tested was milk, which is normally pasteurized. We originally assumed that there would be a big switch to cold sterilization due to the inherent cost advantages. We finally rejected this, after discovering that milk did not change its taste after cold sterilization and most people are accustomed to the burnt taste of pasteurized milk. Today, however, the use of raw milk is increasing by leaps and bounds. Moral: predicting tastes on the basis of paper market surveys is unreliable.

There are some firm facts that seem to be available. People today will pay for a premium program, i.e., movies, sports events, opera, etc. At least if they are in a motel or a hotel they will. Think of the choices the individual in a motel or hotel has, and I think if you travel you can understand why a first-run movie in your room is successful. Another fact is the increasing demand for convenience, service and information.

My conclusion, based on the foregoing, is that there is only one way to properly evaluate the market potential, and you might say that is through the established techniques of test marketing in a limited area. Take a community and install a broadband communications system, or convert an existing system to two-way operation. Install the interactive home terminals on a complete saturation basis. Furnish as many good services as you can and market them. Analyze and project the results to cover other markets. Then there will be some historical data to go by. But in extrapolating this test data, be aware that the process of changing behavior is gradual and evolutionary. Habits of a lifetime will not be modified by the installation of an electronic box.

Look at the office copier market; not only did the sales of machines increase at a phenomenal rate, but, and this is the crucial point, the use of machines increased dramatically after the initial sale. It was one step to introduce the machines to industry, and quite another to have industry change its habits and patterns to make the best use of the office copier. Projecting the ultimate use of the machines first after they were installed would have lead to a completely incorrect estimate of total market potential. This problem holds true for the use of a broadband interactive terminal. How do you estimate changes in behavior and life style? Will family units spend more time at home watching first run movies if they are available?

Several others have previously indicated their belief that the potential market for services, entertainment, and information is available and extremely large. However, the broadband communications networks will not retain a large share of this market without vigorous and specialized marketing on site.

This leads to another conclusion: that in general, the services, entertainment, and information should be handled by a separate or subsidiary group rather than the company operating the cable. The reason for this is the specialized nature of the marketing effort required. The operator, of course, would derive his income from leasing channels on the cable or taking a percentage of the gross. I favor the latter.

I do not wish to make an advertisement of this presentation; however, I would like to review how Theta-Com of California is approaching the problem. We have designed and are installing a complete two-way interactive system in El Segundo. We are performing this test to measure the market which we feel exists for services, data retrieval and entertainment. No matter how many paper studies are performed, there is only one true test of market acceptance; the marketplace. The remainder of this talk sketches the El Segundo test plan and the premises upon which it is based.

The first slide (Figure 1 - Market Size) indicates what we think the market size is. Although this chart was prepared several years ago for another purpose, it agrees essentially with most recent studies made by others. Note that by 1981 we expect that the coaxial cable will be available to 50 million homes, and that about 25 million subscribers will be on the cable. Of that 25 million subscribers, about 18 million will be in systems with more than 2500 subscribers, and about 11 million will be in systems with interactive communication capability of some type. These latter figures were based on assumed projected growth and that equipment is available when needed, the cost of the interactive home terminal is reasonable and that services and information are available and can be marketed profitably.

As you may have observed, we have already made several simplifying assumptions such as that average saturation will be about 50%.

The next slide (Figure 2 - Market Assumptions) shows the additional assumptions we have made in analyzing the quantity of full-scale interactive units required.

The next slide (Figure 3 - Market Plan) describes the test bed that was made available to us. Initially we will install 25 to 30 units that have previously been tested on three simulated systems we now have in our plant.

A. The so-called A-B (dual) cable system, which is the actual equipment that is going to be installed in El Segundo.

B. A single cable two-way system.

C. A single cable system retrofitted with outboard filters and reverse amplifiers for two-way operation. This is intended for those systems that are in existence and wish to convert to two-way service without rebuilding or who may want to be selective on where they initially install two-way.

The next slide (Figure 4 - Test Plan) shows the progress we have made and what the actual test will consist of.

The next slide (Figure 5 - Services to be Offered) shows you our plan for services to be furnished during the El Segundo test phase. It is our opinion that we can realize at an average of at least $10.00 per month of added income per installation. We think we are conservative for the long run. This has a base of premium or pay television with the other items adding incremental income. The figures indicate $120.00 per year of cash flow which will more than pay the carrying charges on the added investments. Based on what we know now, it appears that the capital investment, when the units are in production, will be $200 to $250 for each home terminal equipment set. This figure includes a pro-rata share of the computer and the computer software for the headend. It does not include the cost of converting the cable system to two-way, inasmuch as this is now essentially an FCC requirement. Besides, the incremental cost of two-way versus one-way is rather small today in new construction using modern equipment.

Following are a quick series of slides that show you the actual equipment to be used in the market test. As mentioned previously, our interactive home terminal has been under test on the various types of two-way cable systems and we will install these and similar units in the field, starting in the Fall.

Figure 6 - A-B Cable System - Two Way
Figure 7 - Single Cable System - Two Way
Figure 8 - Single Cable System - Two Way Retrofit
Figure 9 - Computer PDP-11 - Local Processing Center
Figure 10 - Computer Simulator
Figure 11 - SRS - Wall Unit
Figure 12 - SRS - 101 Subscriber Console
Figure 13 - SRS - 102 Subscriber Console
Figure 14 - SRS - Tape Printer for SRS 102

To return to the original question, that of "reducing complex systems to basic parameters leading toward valid predictions of potential cash flow," I feel there is only one way this can be done for interactive home terminals to arrive at a meaningful answer. That is to make an actual installation in the market and evaluate the results. The accuracy of even this direct approach will depend to a large extent on the management of that test, the marketing vigor of the people conducting the test and the foresight and ability of those analyzing the outcome.

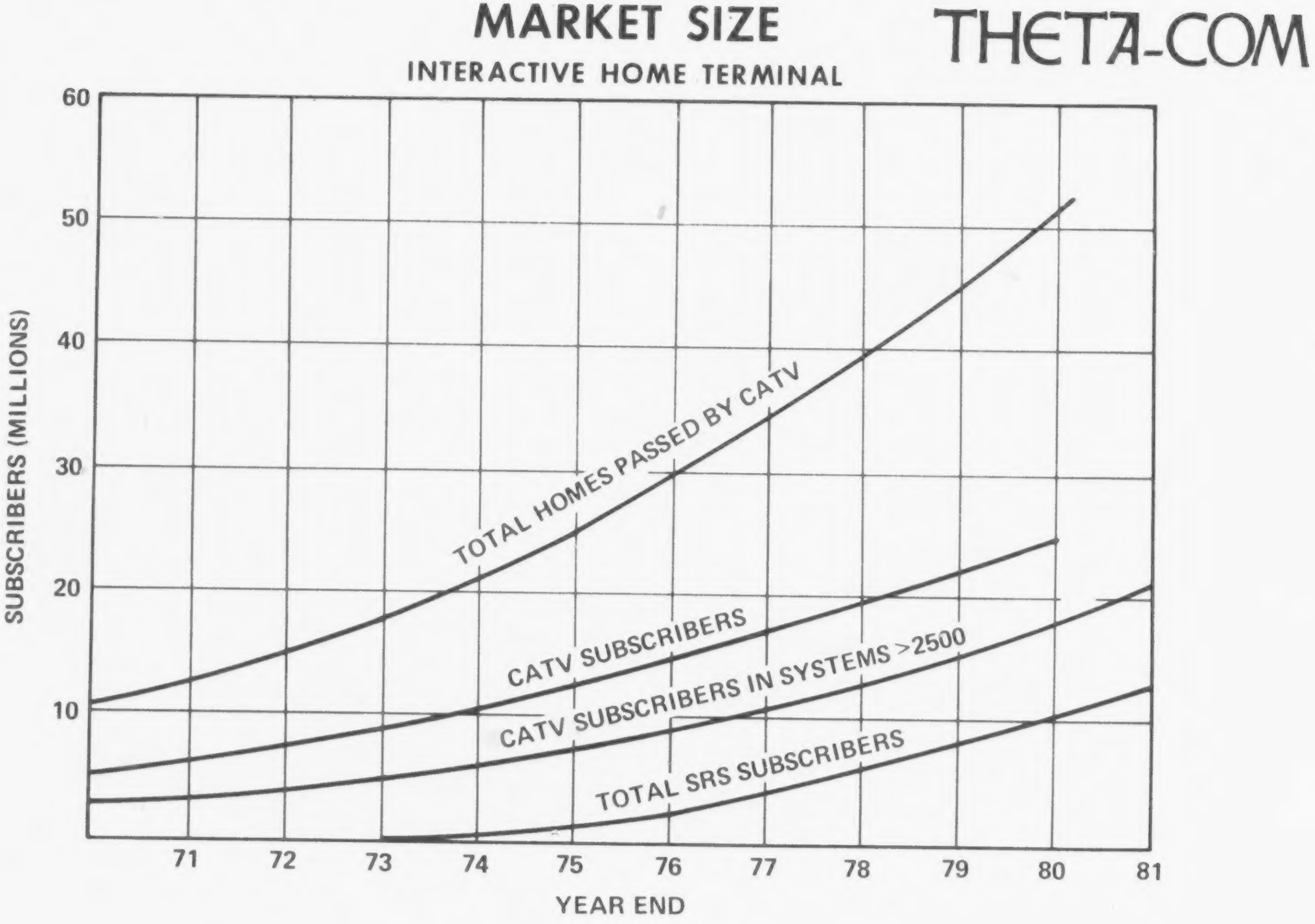
MARKET SIZE
INTERACTIVE HOME TERMINAL
THETA-COM
SUBSCRIBERS (MILLIONS)
60
50
40
30
20
10
71
72
73
74
75
76
77
78
79
80
81
YEAR END
TOTAL HOMES PASSED BY CATV
CATV SUBSCRIBERS
CATV SUBSCRIBERS IN SYSTEMS >2500
TOTAL SRS SUBSCRIBERS

Figure 1

MARKET ASSUMPTIONS

INTERACTIVE HOME TERMINAL

THETA-COM

- INTERACTIVE TERMINAL MARKET WILL BE IN SYSTEMS WITH OVER 2500 SUBSCRIBERS
- PENETRATION IN THESE MARKETS WILL BUILD TO 40% OVER A 5 YEAR PERIOD
- INITIAL INSTALLATIONS WILL BE IN LARGER SYSTEMS
- SYSTEMS WITH BELOW 2500 SUBSCRIBERS WILL GO TO LESS COMPLEX-LOWER COST EQUIPMENT
- MARKET WILL LEVEL OFF BY 1981

Figure 2

FIRST PHASE MARKET PLAN

INTERACTIVE HOME TERMINAL

THETA-COM

EL SEGUNDO TEST BED

- DEMOGRAPHICS
  - POPULATION - 15,620
  - HOMES - 4000
- WHY EL SEGUNDO?
  - PROXIMITY TO THETA-COM
  - CORRECT SIZE
  - TWO WAY SYSTEM TIMING

FIELD TEST

- 30 FIELD TEST MODELS (FTM'S)
  - 15 COMPLETE UNITS
  - 15 UNITS WITHOUT PRINTER
- ENGINEERING CHECK-OUT ON THETA-COM TEST CASCADE
- FIELD TEST
  - CONTROLLED SUBSCRIBER POPULATION
    - 5 CITY OFFICIALS
    - 25 HAC (EXEMPT) EMPLOYEES
  - SIMULATED SERVICES

Figure 3

TEST PLAN

THETA-COM

INTERACTIVE HOME TERMINAL

- EL SEGUNDO AUTHORIZATION
- EL SEGUNDO CATV SYSTEM CONSTRUCTION
- DELIVERY OF TWO-WAY CATV EQUIPMENT
- THETA COM IN-HOUSE TESTS
- 30 FTM'S - EARLY FALL 1972
  - CITY OFFICIALS
  - HAC EMPLOYEES
- 1000 PREPRODUCTION UNITS - FALL 1972
- TEST MARKET - FALL 1973
- PRODUCTION UNITS LATE FALL 1973

Figure 4

SERVICES TO BE OFFERED

INTERACTIVE HOME TERMINAL

THETA-COM

1000 PREPRODUCTION MODELS (PPMS)
SERVICES

1. STANDARD OFF-AIR/LOCAL ORIGINATION TV
2. PREMIUM TV
    - MOVIES
    - SPORTS EVENTS
    - SPECIAL EVENTS
3. RESTRICTED TV
    - DOCTORS - TO BE DEVELOPED
    - POLICE - EL SEGUNDO
    - EDUCATIONAL - LOCAL COLLEGES
4. EMERGENCY ALARMS
    - POLICE - EL SEGUNDO
    - ADT
    - HOLMES
5. ACCESSORY POWER CONTROL
6. CHANNEL POLLING - CONTINUOUS CHECK
    - COMPARISON TO NIELSEN RATINGS
7. HI SPEED PRINT ACCESSORY
    - SMALL SCALE TEST IN SELECTED HOMES
    - TELEGRAM DELIVERY
8. METER READING
    - SOUTHERN CALIFORNIA EDISON
9. OPINION POLLING
    - SELECTED LOCAL/POLITICAL ISSUES
    - INTERACTIVE PROGRAMMING (CHANNEL 28 - ADVOCATE PROGRAM)
10. UP/DOWN STREAM MESSAGES
    - OPERATING FUNCTION
    - SHOP-AT-HOME
        - DEPARTMENT STORES: SEARS-PENNEYS-WARDS
        - ONE-TIME ITEMS
        - MERCHANDISING - COUPONS
        - TICKET SERVICES
        - GAMES
11. SYSTEM DIAGNOSTICS
12. REMOTE SUBSCRIBER ENABLE/DISABLE
    - PREVENTS MISUSE OF SYSTEM
13. FRAME GRABBING
14. VEHICLE MONITORING

Figure 5

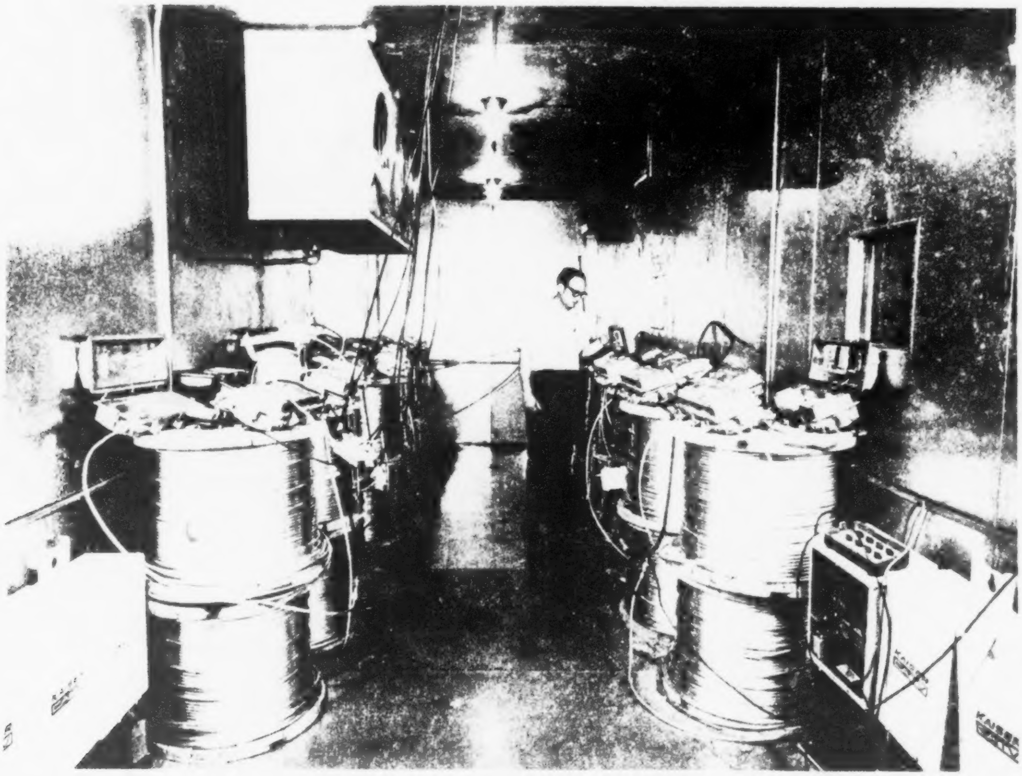

Figure 6 - A-B Cable System - Two Way

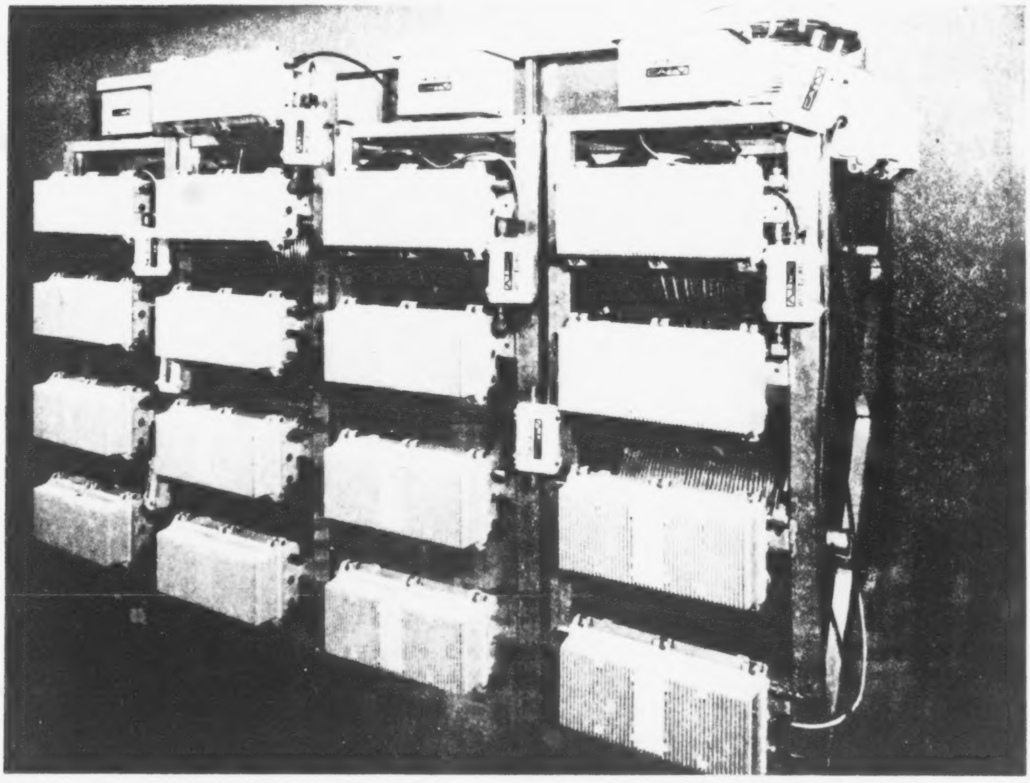

Figure 7 - Single Cable System - Two Way

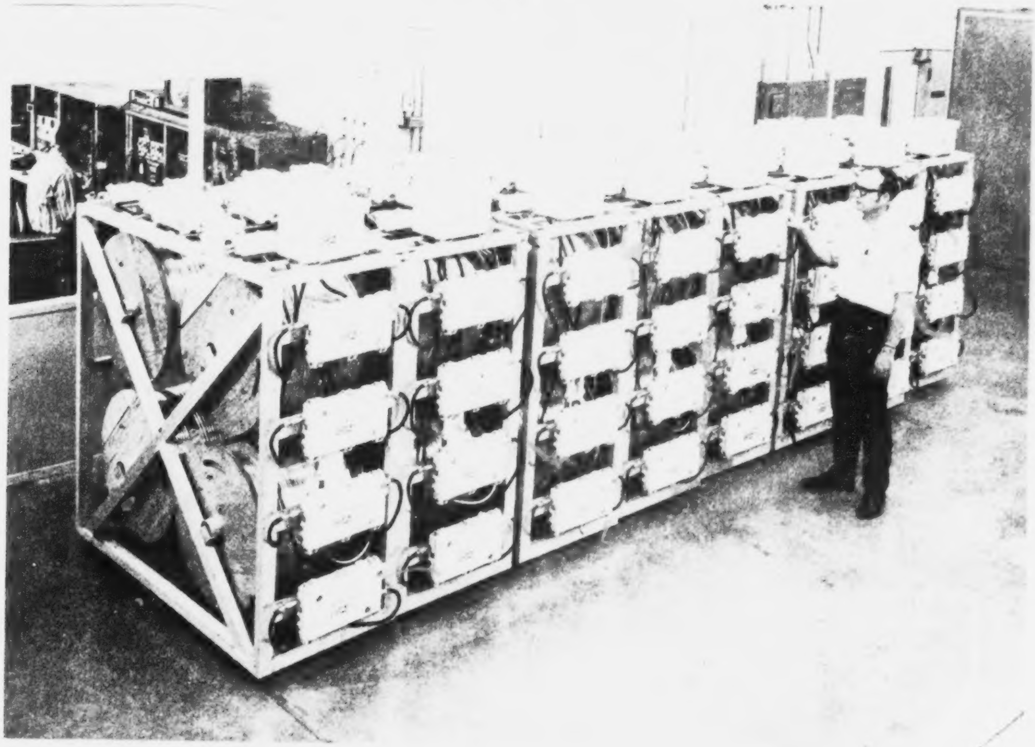

Figure 8 - Single Cable System Two Way Retrofit

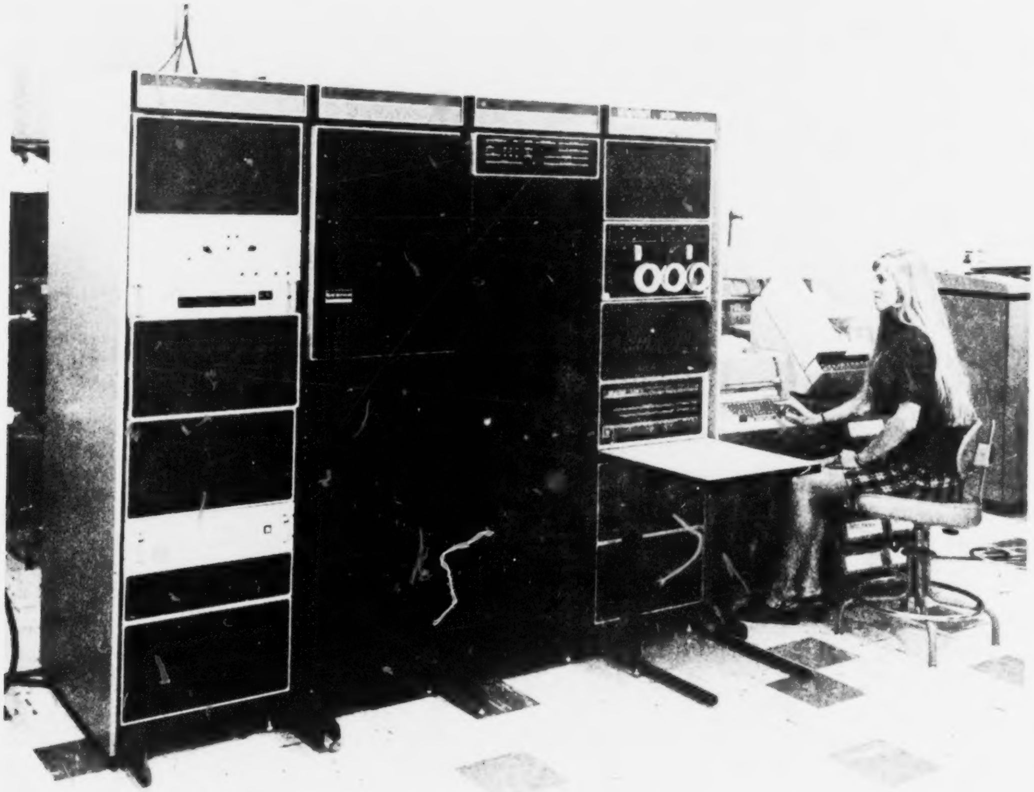

Figure 9 - Computer PDP-11 - Local Processing Center

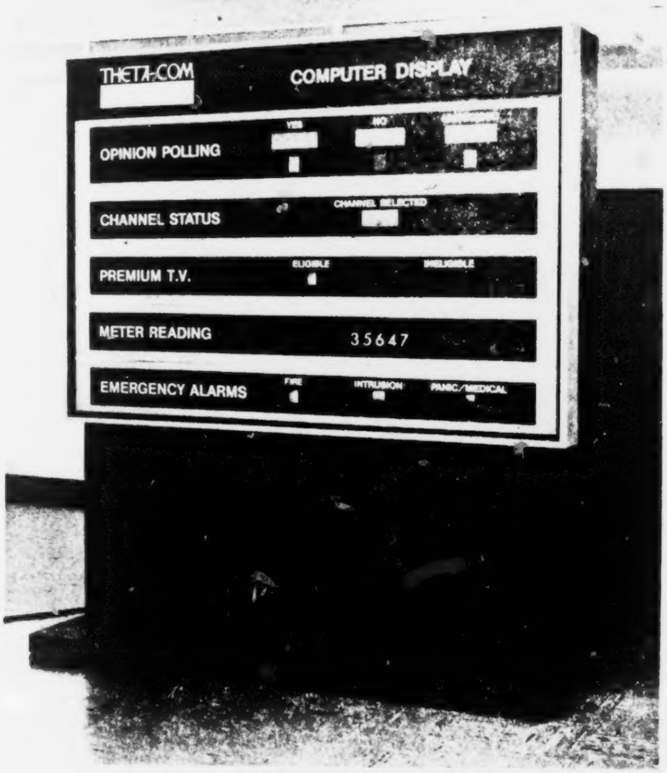
THETA-COM
COMPUTER DISPLAY
OPINION POLLING
YES
NO
CHANNEL STATUS
CHANNEL SELECTED
PREMIUM T.V.
ELIGIBLE
INELIGIBLE
METER READING
35647
EMERGENCY ALARMS
FIRE
INTRUSION
PANIC/MEDICAL

Figure 10 - Computer Simulator

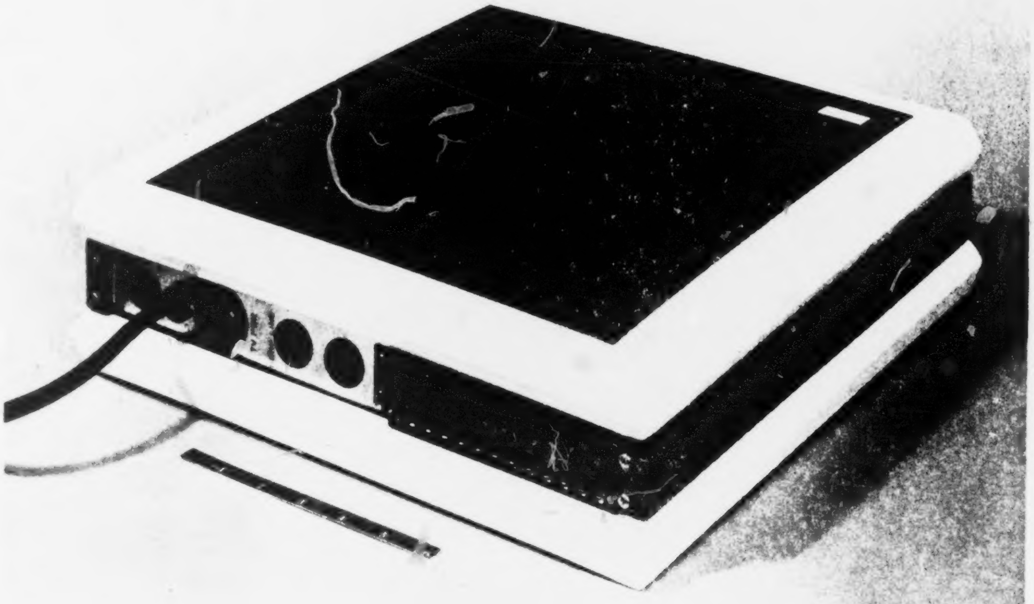

Figure 11 - SRS Wall Unit

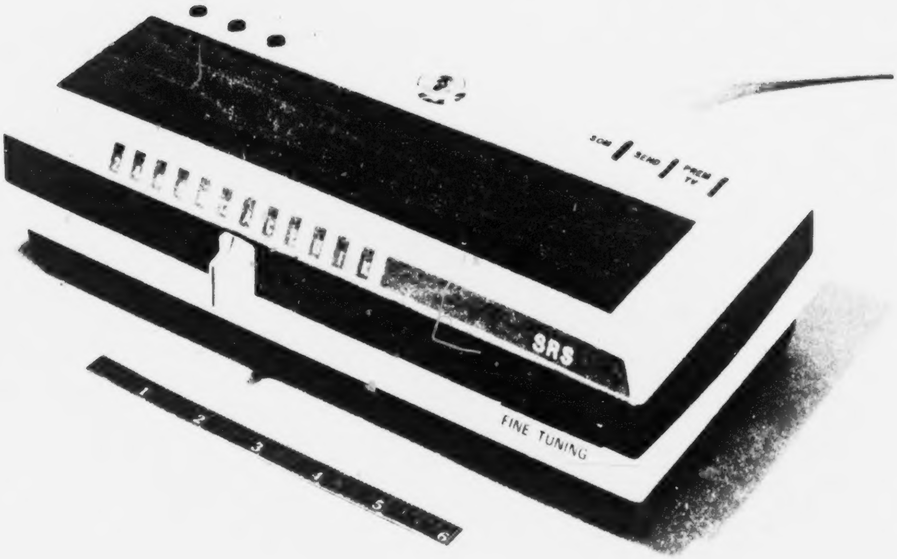
SEND
PREM TV
SRS
FINE TUNING
1
2
3
4
5
6

Figure 12 - SRS-101 Subscriber Console

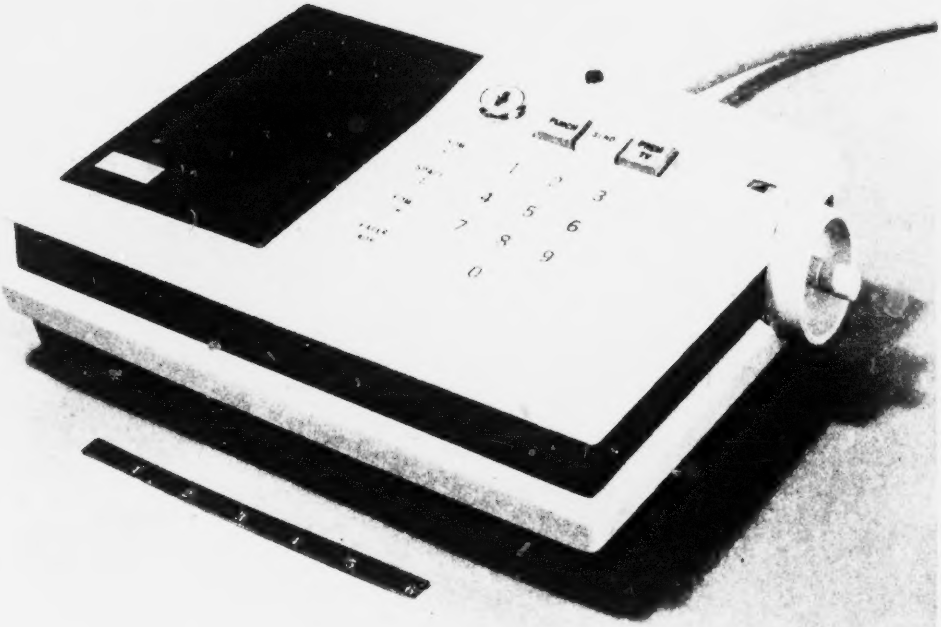
PURCH
SEND
PREM TV
1
2
3
4
5
6
7
8
9
0

Figure 13 - SRS 102 Subscriber Console

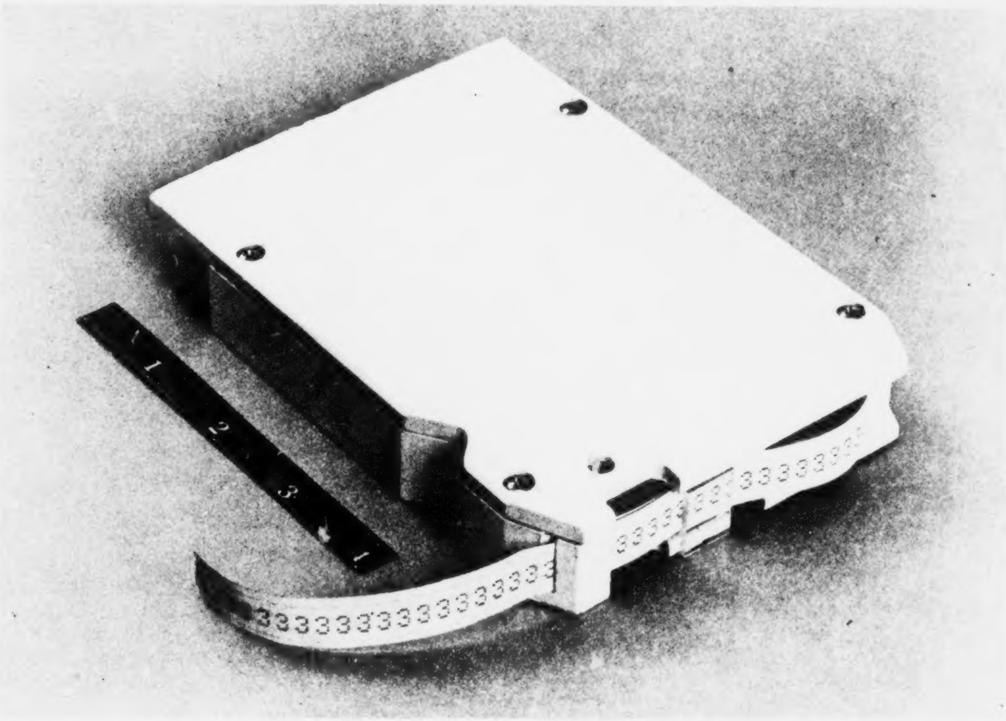
1
2
3
1
3333333333333333
33333333

Figure 14 - Tape Printer - SRS 102

HIGHLIGHTS
TECHNICAL EYE OPENER WORKSHOP

TECHNICAL TRAINING

Sponsor

Society of Cable Television Engineers

Organizer

Jake Landrum
Commco, Inc.
Austin, Texas

Moderator

Joe Hale
Western Communications, Inc.
Walnut Creek, California

Panelists

Galen Gilbert
Elkins Institute
Dallas, Texas

Ed Skies
ICS
Scranton, Pennsylvania

Robert Turkisher
Colorado Electronic Technical College
Manitou Springs, Colorado

Jerry Caddy
Texas A&M Engineering Extension Service
Tyler, Texas

Dr. Albert Fine
College of San Mateo
San Mateo, California

Stan Searle
NCTI
Englewood, Colorado

Reporter

F. E. Jack Stone
UA Cablevision Inc.
Dallas, Texas

A capacity audience attended the Eye-Opener session entitled, "Technical Training," in the Bel Air Room this morning. Moderated by Joe E. Hale, panelists included representatives from N.C.T.I., Elkins Institute, Texas A&M Extension Service, Colorado Electronic Technical College, I.C.S./Intext, and the College of San Mateo.

Each representative described his organization's educational efforts and abilities in the field of Cable Television. Since both Resident and Correspondence Schools were represented and both commercial and non-profit, a broad base was established for the later question and answer period.

The curricula ran the gamut from two weeks to forty-eight weeks for the resident courses, and to 750 study hours for the correspondence courses; from a basic Installer Course to an Associate Degree; and, for a man just out of high school to the experienced system technician. Prices mentioned ran from no tuition (San Mateo College) to $1980 for a complete course (Elkins).

The Question and Answer period was lively and ran into overtime. The panelist from C.E.T.C. was challenged on his statement that his school has for three years offered twelve scholarships to black students and to date has not received a student. He was asked how he had advised the black community of such scholarships (Press, Department of Labor, and black civic organizations) and what out-of-pocket expenses a student could expect if he were awarded one ($200 per month)?

The discussion was continued in an informal manner after the session was concluded by the Moderator.

HIGHLIGHTS
TECHNICAL SESSION

FCC TECHNICAL RULES AND STANDARDS

Chairman

Douglas C. Talbott
Cox Cable Communications
Atlanta, Georgia

Speakers

Sydney R. Lines
Federal Communications Commission
Washington, D.C.

Norman Penwell
Malarkey, Taylor & Associates
Washington, D.C.

Jerald S. Crusan
Jerrold Electronics Corporation
Philadelphia, Pennsylvania

Linley Gumm
Tektronix Inc.
Beaverton, Oregon

Reporter

Joseph S. Gans
Cable TV Company
Hazleton, Pennsylvania

The panel on the FCC Technical Rules and Standards Session consisted of a member of the FCC staff and qualified engineers who explained the rules and methods of complying with these rules using the currently available test equipment and techniques.

1. "Cable Television Technical Standards - Concepts and Interpretations" - Sydney R. Lines

Mr. Lines announced that the newly adopted rules and standards are now in effect. Minimum signal standards have been set, but the maximum over-load levels are not known at this time because it has not yet been determined what a TV set will tolerate.

Frequency tolerance standards for top-of-set converters have been somewhat relaxes, but, as technology standards improve, they will become more stringent. Variation of signals in the CATV systems cannot be more than 12 dB per 24 hours. This means the system will have to compensate for rapid changes in temperature. Radiation tolerance will include both signals leaving the cable, as well as signals getting into the cable such as high powered communication transmittors.

2. "Critical Steps to Compliance" - Norman Penwell

Mr. Penwell further elaborated on the FCC Technical Standards. He is quoted as saying:

"A system is further defined as 'each separate and distinct community or municipal entity served with cable television facilities, even if there is a single head-end and identical ownership of facilites extending into several communities'. Each system thus defined must comply separately with the new rules.

"New systems may not commence operation nor may existing systems add television broadcast signals until they have received a certificate of compliance. Existing systems cannot continue carrying television broadcast signals beyond March 31, 1977 without obtaining a certificate of compliance."

3. "CATV Distortion Measurement Techniques" - Jerald S. Crusan

Mr. Crusan mentioned that test equipment will have to be improved, technical men need to be better trained, and performance tests must be made. Lack of these will no longer be accepted as an excuse for complying with the rules.

Mr. Crusan suggests that the minimum equipment should consist of a spectrum analyzer, wave form analyzer, field strenth meter, oscilloscope, attenuator, square wave generator, and a simultaneous sweep generator.

4. "Key Frequency Parameter Measurements and Instruments" - Linley Gumm

Mr. Gumm explained the more complicated measuring techniques. He presented slides which demonstrated that a Spectrum Analyzer can make 9 out of 10 of the measurements required by the FCC rules. Mr. Gumm also explained how the spectrum analyzer can make the following tests: Amplitude Standards, Frequency Standards, CATV System Flatness Specifications, System Fault Standards, Isolation, Radiation, and Video Characteristics.

This technical session explained thoroughly the new FCC requirements and enlightened the understanding of cable television system measurements needs.

Great interest in this session was obvious due to the large crowd leaving standing room only. The questions that were asked and the serious concern that the cable operators have for the new regulations caused the session to continue beyond its designated time.

CABLE TELEVISION TECHNICAL STANDARDS --- CONCEPTS AND INTERPRETATIONS

Sydney R. Lines,
Federal Communications Commission

As cable television enters its third decade, the Federal Communications Commission has issued for the first time a comprehensive set of rules to provide regulatory guidance for the industry. An analysis of the new rules suggests that they are intended to accomplish several things:

---to encourage cable television to grow and to function as a social tool;

---to force it to expand to perform new functions, provide new services, assume new responsibilities;

---to protect existing communications channels to an extent consistent with the public interest;

---to provide a reasonable assurance that the subscribing public receives a television reception service of at least a minimum prescribed quality.

These various aims do not necessarily lead to the same ends. As you may have perceived in studying the new rules, compromises have had to be made and complicated approaches have had to be devised; relatively simple matters have become complex.

A reading of the new rules shows that throughout the various sections and subsections, technical considerations are interwoven with administrative and operational requirements, seemingly in nonchalant unconcern and without due regard to their impact on engineering. This seems to be unavoidable, either because of the nature of cable television operations, or because of the regularatory approach seen necessary by the Commission.

The subject of this particular discussion is limited to that special group of rules which will be found in Subparts A and K of the new Part 76 of the Commission's rules. These are the technical requirements, performance parameters, and definitions which cable television engineers and technicians will find of most immediate interest.

Insofar as these technical requirements are concerned, the Commission's approach has been to recognize that the end product---the television signal delivered to the subscriber---is the matter of paramount concern. (In the future, this may change.) The Commission has avoided as much as possible any regulation of the hardware or of the distribution system design, preferring rather to impose requirements on the quality of the signals delivered to the subscriber. For this reason you will not find specifications on, for example, the maximum noise figure of amplifiers or head end equipment, or on the frequency stability of the channels within the system. Instead, there are limitations on the minimum signal-to-noise ratio and a prescribed tolerance on the frequency of the visual carrier frequency as it is delivered to subscriber terminals.

Cable Television signal categories.

The Commission's approach also involves consideration of the multitude of signals and activities which soon will characterize cable system operations. With local origination to be required of many systems, the question arises: should the standards for locally originated programs be the same as for off-air signals? Cable systems are expected to provide facilities for unspecified upstream communications---two-way non-voice signals. What kinds of requirements should be imposed on such signals? With the possibility of pay-TV or encoded television occupying some of the cable spectrum, what standards and what limitations will be necessary? As between these various operations, what are the relative priorities for interference protection? Obviously, no single set of standards can be applied to such a widely ranging---and still uncertain--- gamut of signals.

Therefore, the Commission provided for four categories of cable television channels which are distinguished by the kinds of signals they carry. The definition of these four categories are found in the special section of definitions---Section 76.5 of the new rules. Briefly, Class I cable television channels are channels which carry off-air broadcast television signals. Class II cable television channels are those channels carrying locally originated programs ---"cablecasting." Class III cable television channels are those devoted to other forms of downstream communication such as facsimile, encoded TV, private or closed circuit TV, digital or analog data, off-air FM or AM signals. Class IV channels are those which carry upstream or "return" communications. At this time, we can imagine only some of the kinds of signals upstream communications will involve in the future. I contemplate that the future may see the Commission setting up additional channel categories.

As a result of setting up this classification, as the cable industry grows the Commission can proceed with a scheduled expansion of rules and technical standards for each of the categories. At this time, obviously, the bulk of cable operations is concerned with traditional CATV, and with some ventures into local origination of various types. Thus the technical standards which the Commission adopted last March are applicable only to Class I cable TV channels.

Class II cable television channels probably will receive attention soon. Preliminary staff studies already are underway. Then, as experience dictates, specific regulations and technical standards for Classes III and IV cable television channels will be considered. The possibility also has been investigated of providing a separate set of technical standards for cable systems operating in the top 50 markets, recognizing that in these markets there may be a broader economic base to support increased performance requirements.

However, with respect to Class I cable TV channels, probably the first order of business will be to augment the technical standards already adopted by adding subsections on such matters as ghosting and color performance, possibly other parameters. Before completing this, however, the Commission should have acquired enforcement experience with the rules already adopted and some additional measurement methods should be developed and tested.

Cable TV Industry Advisory Committee.

In adopting this procedure for gradually expanding the rules and technical standards, the Commission recognized that it would have to depend upon technical advice from various segments of the cable television industry. As outlined in Report and Order, the Commission served notice that it would call for the formation of a cable advisory committee. As a result, the Cable Bureau has been deluged with the names of technical experts who have been nominated to serve on the Committee. Although the exact procedure which will be followed has not been determined in finality yet, it seems probable that a Steering Committee will be formed from among the large body of nominees. And then, to accomplish individual missions, smaller working groups will be formed. It is our view that work on augmenting the existing technical standards to provide performance requirements and measurement methods for such things as envelope delay, differential phase, and possibly cross-modulation should come first. Possibly at the same time, a full-scale study should be launched to develop technical standards for Class II cable TV signals. One of the unresolved questions here is: Should Class II cable signals be required to adhere to broadcast fidelity requirements, or should less rigid standards be permitted? One approach would require a substantially higher investment in equipment and technical personnel for which the subscriber inevitably would pay. The other would permit a lower standard of technical performance, encouraging cable operators to invest more effort in local origination, public access, and special educational or public service projects. Insistence upon broadcast standards of quality would eliminate, at least for a time, the use of relatively inexpensive videotape equipment which, up to now, has been used extensively in CATV origination. However, experience to date indicates that the 1/2-inch tape, while stimulating inovation in programming, has been somewhat less than satisfactory in practical performance.

Cable System definitions.

Before discussing the standards themselves, I'd like to invite attention in particular to two of the definitions. Section 76.5(ee) defines a very important point in the system--the subscriber terminal. This is the point of interface between the property of the cable system and the subscriber-owned equipment. If a set-top converter is supplied by the system, and is the last item of cable equipment before connecting to the subscriber's receiver, then the converter output terminals are the subscriber terminals for that subscriber. If the system supplies a length of cable and a balun transformer at the subscriber's receiver, then the balun output forms the subscriber terminals. The subscriber terminals are the points in the system at which conformity with the technical standards is determined.

The other definition concerns "system noise," Section 76.5(ff). Here, the noise of interest is not confined simply to thermal or gaussian noise, but includes all the various disturbing effects which are random or fluctuating in nature, whether it is produced by thermal effects, component leakage, modulation by-products, or atmospheric processes. In practice all of these disturbances are somewhat similar in nature and combine to have a degrading effect upon picture transmission. We see no real merit in attempting to treat them individually by setting up separate specifications for thermal noise and the multiplexing noise which results from transmitting simultaneously a number of signals through a common channel. So the Commission adopted a definition which lumps all of these phenomena together, recognizes that the combination is an unwanted interference to the picture, and provides a minimum signal-to-unwanted-interference ratio which must be met at the subscriber terminals.

Performance Tests.

Now, turning to Subpart K of the new rules, we find the first section (76.601) is entitled "Performance tests." This section defines the responsibilities of the cable system operator and sets forth several matters which he must undertake in order to fulfill those responsibilities. In addition to certain logging and record-keeping, the cable operator is required to make performance tests "directed at determining the extent to which the system complies with all the technical standards..." These are to be made annually and are expected to be made at three widely separated points, at least one of which is representative of subscriber terminals farthest in terms of cable distance from the system input.

Even though the performance tests are required to be made annually at only 3 points on the system, successful completion of the performance tests does not relieve the system of the obligation to comply with all pertinent technical standards at all subscriber terminals. Furthermore, if it is necessary, additional tests on the system may be required by the Commission in order to secure compliance at subscriber terminals.

The approach the Commission has taken here recognizes two things: the impracticability of requiring annual full performance tests at every subscriber terminal in the system, and the necessity of requiring the cable operator to undertake monitoring performance on a routine but thorough basis. Why require only three measurement points? We consider that protection of the subscriber's interests could be achieved only by increasing the number of measurement points to several dozens, which number becomes unrealistic. So the rationale is to rely upon the basic requirement that every subscriber is to receive a grade of service which is obtainable under the technical standards, that measurements demonstrating compliance with the standards would be made only as necessary, but that as a means of monitoring the general operation of the system, a full set of measurements must be made at a minimum of three points annually. This is not a "Proof of Performance" nor is it intended to be. It simply is a requirement that the system operator take minimum steps to maintain his system properly, become capable of making all the required system measurements, and to keep those data for future reference.

We think this new requirement for a measurement capability is a substantial step forward. Our experience to date, when being involved in disputes over picture degradation or poor service, indicates that the preponderant majority of systems in trouble with the law, so to speak, do not have an adequate measurement capability. Our field personnel find, time and again, that cable complaints they have been called upon to investigate involve systems whose operators plead that they don't know how to measure some of the important performance parameters, or that they do not have the necessary equipment, or do not have personnel with the necessary expertise. This is no longer a valid excuse. The performance tests rule is effective now.

Technical Standards.

The next Section (76.605) of Subpart K is entitled "Technical Standards." Here are outlined about a dozen different parameters which affect the quality of cable service and for which threshold or limiting values are listed. These technical standards are applicable to the system performance as measured at any and all subscriber terminals. It may be of use to discuss several of them here.

We were surprised to find that, of all of the technical standards adopt d, the matter of visual carrier frequency tolerance occasioned the most comment. The standard which the Commission adopted provides for a frequency tolerance of plus or minus 25 kHz for the visual carrier. However, in recognition of the difficulties of obtaining a frequency stability of this amount in set-top converters of current design, the Commission provided further that, when set-top converters were supplied by the cable system, the applicable tolerance is plus or minus 250 kHz. Objections to this latter tolerance have been that it is too loose, that it is too tight, and that it doesn't apply to signals within the system. We agree with all three objections.

A tolerance of ±250 kHz does not assure that the adjacent channel traps in most television sets will provide the protection that the manufacturer feels he builds into his receiver. In this respect that tolerance obviously is too loose. However, after looking at the frequency stability which reasonably can be expected from the present generation of set-top converters (and at the stability of present TV receiver tuners which are of not greatly different quality), we were unable to conclude that a substantially tighter tolerance could be specified in 1972. We are in agreement, however, with suggestions that soon a tighter tolerance should be required and that both users and manufacturers should plan for this, now. The matter of tolerances may be a future subject for consideration by the Cable TV Industry Advisory Committee.

The other complaint about the frequency tolerance specification involves a situation like the following hypothetical case. Suppose a system is receiving channel 8 off the air and carrying it straight through the system to the subscribers' converter inputs unchanged in frequency. It also is receiving a UHF station and converting it to channel 7 for delivery to the subscriber converters. Now assume that because of instability in the head end equipment, the channel 7 signal drifts upward and overlaps the channel 8 signal as they appear at the input to the converter. The subscriber attempting to view channel 8 gets a lot of disturbance in his picture from channel 7. And he can't tune it out becuase the converter simply shifts both frequencies together. The converter adjustment permits either signal to be delivered to the subscriber terminal within tolerance, but neither can be delivered without interference. The required tolerance is not applicable to signals within the cable system. To protect the subscriber, the argument is made, we need an additional specification.

The additional specification already is in the rules, Sections 76.605(a)(9) and 76.605(a)(10). Either or both may apply. If the disturbance to channel 8 from channel 7, or vice versa, is great enough to exceed either specification, the cable operator is obligated to apply the appropriate correction. If he can clear the problem without correcting the channel frequencies within the system, that's his prerogative, but it seems obvious that the first thing he would do would be to get channel 7 back on frequency.

To sum it up, I think the best we can say about cable frequency tolerance is that, as experience indicates and as technology permits, it will be made more restrictive. The cable operator should plan on that.

Signal levels.

Section 76.605(a)(5) is a specification on the permissible variation in levels which may be delivered to subscribers. The most vigorous reaction to this specification comes from broadcasters. Some feel strongly that it is imperative that the Commission specify a maximum signal level, on the grounds that if too strong a signal is delivered by the system, overloading may occur in the subscriber's receiver, causing picture degradation. The Commission's approach recognized that we don't know what the maximum permissible signal should be--it varies from receiver to receiver and from channel to channel. What's more, there is disturbing evidence that the overload threshold may be substantially lower when the imput consists of several strong signals on adjacent channels than when the input is only a single strong signal. We simply do not know enough at this time about the effects of applying a dozen or two dozen strong adjacent channel signals to present day receivers to adopt a safe upper limit on visual signal level. The qualitative limit which the Commission adopted is preferable, I think, to an inflexible quantitative limit for which we have little authoritative measurement data to justify. The qualitative limit which the Commission adopted also gives the cable engineer a latitude in the design of his sytem which should help him cope effectively with the myriad individual circumstances he encounters in real life.

The provision in 76.605(a)(5) regarding the maintenance of signal level requires clarification. As adopted by the Commission, the rule reads, in part, "The visual signal level on each channel shall not vary more than 12 decibels overall..." The provision has not been thoroughly understood. I think it will be modified soon to read, "The visual signal level on each channel shall not vary more than 12 decibels within any 24-hour period..." The purpose of the requirement is to restrict the permissible variation caused by temperature fluctuations, amplifier instability, switching operations, or whatever, to no more than 12 dB over a day's operation.

Cable system radiation.

Section 76.605(a)(12) also may undergo some modification shortly. This is the provision restricting radiation from the cable system. The rule as adopted by the Commission fails to make clear a rather obvious qualification: radiation from the system is not amenable to measurement at subscriber terminals as are the other technical standards but should be measured by techniques outlined in a following section of the rules.

In this connection, radiation from the system also may provide an indication of leakage into the system. There have been several reports recently of problems due to pick-up of land mobile signals in the 150-170 MHz band. Interference of this sort can be particularly difficult to find and eliminate unless the cable system is well shielded and grounded in an effective manner. The land mobile signals are intermittent or sporadic--on-again-gone-again---but they can cause no end of displeasure to your subscribers who may want to watch midband channels. It is strongly recommended that the cable operator inaugurate a frequent schedule for checking both for radiation from the system and leakage into the system.

Measurements and procedures.

The commission has adopted a rather lengthy rule for the cable operator's guidance with respect to measurement methods. The rule is not intended to restrict the cable operator to only those methods described in the text. It is aimed rather at illustrating techniques and procedures which probably will be accomplished with ease and acceptable accuracy. Other methods and variations upon the outlined methods may be acceptable. And, conversely, the mere use of a suggested technique will not assure the operator that **his** measurements will be found acceptable. The Commission will review the statements concerning the measurement technique and the resulting data, looking for evidence of technical competence, integrity, and accuracy. In making these measurements, the operator or his consultant must not ignore the opening statement of this section: "Measurements made to demonstrate conformity with the performance requirements set forth in Sections 76.601 and 76.605 shall be made under conditions which reflect system performance during normal operation..." Obviously, some system measurements cannot be made with the system under completely normal operations. It may be necessary to disconnect antennas, drop a channel, or remove a pilot tone in order to accomplish some measurements. However, steps should be taken to ensure that the rest of the system functions as normally as possible. The purpose of the language is to preclude making measurements which bear no real relationship to conditions of normal operations.

It is recognized that, in promulgating a group of technical standards and in launching the necessary enforcement effort the standards will entail, the Commission in a sense is pioneering in an area where regulation has not been applied before. A great deal of attention probably will be paid to reviewing the cable standards program and its progress and possibly some early readjustments of the rules will be made. Certainly, extension of the technical standards to cover other facets of cable operation is to be expected soon. I think that the cable operator should recognize and appreciate that all this effort is evidence of the high expectations which the government and the public have for cable communications.

CRITICAL STEPS TO COMPLIANCE

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Malarkey, Taylor & Associates

These remarks are limited to the steps required to comply with the technical aspects and standards of the recently adopted (2 February 1972) rules for Cable Television Service, Part 76, Subpart K, Technical Standards of the FCC Rules and Regulations on Telecommunication.

Initially, the rules exempt any system that serves fewer than 50 subscribers and those systems that serve only residents in apartment dwellings under common ownership, control, or management. All other systems must comply.

A system is further defined as "each separate and distinct community or municipal entity (including single, discrete, unincorporated areas) served with cable television facilities, "even if there is a single head-end and identical ownership of facilities extending into several communities". Each system thus defined must comply separately with the new rules.

New systems may not commence operation nor may existing systems add television broadcast signals until they have received a certificate of compliance. Existing systems cannot continue carrying television broadcast signals beyond March 31, 1977 without obtaining a certificate of compliance (unless application was made at least 30 days prior to the need for certification).

Para 76.13 identifies methods of filing applications for certificates of compliance for the four different categories of applicants; (1) cable systems not operational prior to March 31, 1972, (2) systems authorized to carry signals prior to March 31, 1972, but were not yet operational, (3) systems proposing to add television signals, and (4) systems with existing operations. No standard form is prescribed but the information to be filed for each of the above categories must be submitted in three copies to the FCC.

Para 76.201 requires systems of 3,500 or more subscribers to designate a channel for the exclusive use of operating as a local outlet, originating programming to a significant extent and providing facilities for such local production, (subject of course to disposition of the current litigation of this issue in the courts).

Systems that operate in whole or in part within one of the major television markets must comply with the minimum channel capacity and access channel rules. For new systems commencing operations after March 31, 1972 the rules are effective immediately, other systems must comply by March 31, 1977 or earlier if television signals are added to the system or if access channels are designated, the rules governing their operation will apply.

These rules require a minimum of 120 MHz (20 television channels) be made available for immediate or potential use; that 6 MHz of capacity be made available for Class II and III channel use for each Class I channel carried; that the distribution plant be capable of non-voice return communications; that at least one channel shall be designated for each of the access categories, general public, education and local government; that at least minimum equipment and facilities be made available for program production on the public access channel; that unused time on the local origination and designated access channels be made available for leased access services, and further, when all of these channels are in use during 80% of the week days for 80% of the time during any consecutive three-hour period for 6 consecutive weeks, a new channel shall be made available within 6 months for any or all of these purposes.

Subpart K of the Rules, relating to Technical Standards is effective immediately, that is, March 31, 1972. Para 76.601 of the rules requires that each system be designed, installed and operated in a manner that fully complies with the rules in this subpart. This means that immediately system operators must maintain in their local system office a listing of the cable television channels that the system delivers to its subscribers, the station(s) whose signals are delivered to subscribers on these Class I cable channels, and a specification for each subscriber of the minimum visual signal level maintained on each Class I channel under normal operating conditions.

Each system operator must conduct performance tests at least once during each calendar year; this means that the first set of measurements must be made and must be kept on file at the system's local office by no later than December 31, 1972. Thereafter, intervals between measurements may be as long as 14 months, but in any event, measurements must be made and kept on record for each calendar year (including 1972) for five years, and must be made available for inspection to the Commission or the Commission's field representative on request.

The tests are to be made to determine the extent to which the system performs in compliance with the standards prescribed in para 76.605. For new systems commencing operations after March 31, 1972 compliance with the standards in 76.605 is immediately mandatory; for systems in operation prior to March 31, 1972 compliance is not mandatory until March 31, 1977 except for the rules governing radiation which are in effect immediately.

Performance tests must be made on each Class I television channel identified above in the listing and for each system/community or entity satisfying the Commission's definition of CATV system. Further, for each Class I channel, the tests shall be performed at three widely separated points in the distribution system of which at least one is representative of the subscriber terminals most distant from system input. Although Para 76.605 (a) requires performance to comply with the rules at any subscriber terminal, the measurements themselves may be made at convenient monitoring points if the technical data are included to relate the measured performance to the performance as would be viewed through a nearby subscriber terminal.

This provision would allow, for example, a system to establish high signal level monitoring points out of the last line extenders in the distribution system. Generally there would be no active devices beyond this point and the subscribers terminals. In the case of systems using set-top converters we believe that laboratory measurements can be used to relate their performance to a subscribers terminal. This provision of the rules thereby relieves any system operator of the necessity to gain access to subscribers property to make performance measurements.

Part of the Rules with which systems must comply and maintain records of compliance for inspection by the Commission are those relating to radiation. The radiation limitations are effective immediately and measurements demonstrating this fact must be on hand at the local system office no later than December 31, 1972. As presently defined in Para 76.601 these measurements must be made on each Class I television channel at each of the three widely separated subscriber locations, but the intent of the rules as just explained by Mr. Lines of the FCC is to include any radiation from the cable system, and the precise wording of the rules will probably be amended to effect this intent.

Next, a few comments about some of the measurement problems. For example, measurement of visual carrier frequency is not as easy as it might sound. A calibrated signal generator can be mixed with each visual carrier and the zero beat identified with either a high resolution spectrum analyzer or on the screen of a television receiver. Using a receiver for this purpose though presents problems since the signal generator carrier will beat with each of the 15 kHz sidebands of the visual carrier and absolute identification of the correct zero beat is difficult. Alternatively a frequency counter can be used, sampling the visual carrier. The modulation of the carrier must be removed before the counter will read properly. The "black box" to do the modulation stripping does not yet exist as off-the-shelf equipment so each engineer will have to develop his own equipment for this purpose.

I see no reason why the aural carrier need be measured since its relationship to the visual is established at the broadcast transmitter and carriage on cable does not affect this relationship. In the few cases of Class I channels receiving inputs from microwave systems that separate the visual and aural carriers, or from direct studio feeds, the aural carrier must then be measured to assure compliance with the rules.

The wording of para 76.605 (a) (2) appears to exempt systems using converters from the ± 25 kHz tolerance and to apply only the ± 250 kHz requirement, however the intent of the rules, which will no doubt be clarified, is not to relieve the system of the requirement for ± 25 kHz tolerance but to restrain the visual carrier frequency stability as viewed through the converter at the subscribers terminals to ± 250 kHz.

In complying with the visual signal level requirements the critical aspect is in maintaining calibration accuracy of the signal level meter. Typically in broadcast field measurements it is customary to calibrate the field meter before and after each reading, and if the calibration has changed the process must be repeated until one is satisfied the calibration has held constant during the measurement process. Most broadcast field strength meters have built in calibrators for this purpose. No such instrument is available for the CATV industry, yet accurate signal level measurements are the very keystone to proper system operation. The adjustments of amplifier input and output levels, governing overload distortions and noise are critically dependent upon accurate level measurements, yet this is probably typically the single weakest link in system operation and maintenance.

A good calibration procedure will be mandatory in complying with the rules; the calibration should be traceable to the National Bureau of Standards. For example, a laboratory signal generator with calibrated output, a bolometer power meter to transfer d-c calibration to r-f, or the Selby Micro-potentiometer can be used to accurately calibrate the signal level meters.

A calibrated spectrum analyzer would also be most useful for these level measurements since photographs could be taken as records of the measurements, and the single display could show the level relationship between all visual and aural carriers that are required of Para 76.605 (a), (4), (5) and (6).

The hum and low frequency disturbances are to be measured relative to the visual signal level (sync tips), which will require baseband equipment such as an oscilloscope to display the bar and window test signal. Measurement of window tilt then will be evidence of low frequency response.

Channel frequency response can be measured with a signal generator input at the system head-end. In the case of wide-band antennas such as log-periodic the input at the first active amplifier seems satisfactory; in the case of a single channel yagi antenna, open field measurements may be required to demonstrate compliance. In the case of tower mounted preamplifiers, the input must be to the preamp and since this is going to be physically difficult we would recommend a separate downlead be installed and used for this purpose.

Someone would still have to climb the tower to make the changeover for the measurement but test equipment would not be necessary on the tower. New system design ought to include facilities for coaxial switching at the tower mounted preamp input for these test purposes. The sweep or signal generator obviously must operate through the UHF band.

The NCTA Standard 005-0669 describes a method of system noise measurement that can be accomplished using the signal level meter, but the requirement of para 76.605 (a) (9) holding off-set co-channel interference to 36 dB will probably require a high resolution spectrum analyzer for identification and level measurement of the co-channel(s). If the interference is limited to one easily identified off-set co-channel the level can be ascertained by measuring the level of the 10 or 20 kHz off-set beat. With the level of the desired channel and the beat frequency both known, the level of the interfering co-channel can be calculated.

Compliance with Para 76.605 (a) (10) may also require the use of a spectrum analyzer. It is probably not going to be possible to measure discrete interfering signal levels at -46 dB with a field strength meter as indicated in Para 76.609 (f) of the rules. If, for example, system noise is at -40 dB, the typical SLM will read approximately -43 dB (allowing corrections for bandwidth, peak-to-rms, and detector non-linearities). A discrete interference at -46 dB would therefore be about 3 dB below the noise level and impossible to identify.

CATV DISTORTION MEASUREMENT TECHNIQUES

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The general industry acceptance of mid and superband channels heralds a new era in system maintenance. To meet the challenge one must understand the factors that contribute to the distortions and develop the techniques necessary to diagnose and remedy problems while in their infancy. The measurement of CATV distortions is not a difficult assignment, however it does require proper instrumentation.

One of the major points of this paper is to present one important fact, YOU CANNOT MEASURE COHERENT DISTORTIONS WITH A FIELD STRENGTH METER. To attempt to measure a component 55 dB below carrier in the presence of a 40 dB Carrier-to-Noise ratio is like looking for the proverbial needle in a haystack. The methods described in this paper are based on two receiving devices, (a spectrum analyzer and a wave analyzer).

The spectrum analyzer is a swept receiver that provides a CRT display of amplitude versus frequency. It shows how energy is distributed as a function of frequency, displaying the fourier components of a given waveform.

The wave analyzer can be thought of as a finate bandwidth window filter which can be tuned throughout a particular frequency range. Signals located on the frequency spectrum will be selectively measured as they are framed by the window.

Both of these units have one thing in common, narrow bandwidth. When the wave analyzer has a bandwidth of 25 cycles it will show an improvement over the 600 kc F.S. M. of 44 dB in regards to the measurement interference caused by system noise. A spectrum analyzer with 300 cycle bandwidth will offer a 33 dB improvement. Basically this means you can measure a second order component 66 dB below carrier in the presence of a 40 dB carrier-to-noise ratio, with either instrument. The F.S.M. is limited to about -35 dB below carrier at the same carrier-to-noise ratio.

SECOND ORDER

The mathematics that follow are not of any great importance to anyone other than a designer, however there are a few important aspects that the formulas clarify.

(1) Second order increases one dB for each dB increase of amplifier output level.

(2) Second harmonics are 6 dB less than sum and difference beats for the same output carrier levels.

SUM AND DIFFERENCE LEVELS IN dBmV AT AMPLIFIER OUTPUT

$L\,a\,b = K_2 + La + Lb \quad (\text{at } f_a \pm f_b)$

$L\,b\,c = K_2 + Lb + Lc \quad (\text{at } f_b \pm f_c)$

$L\,a\,c = K_2 + La + Lc \quad (\text{at } f_a \pm f_c)$

SECOND HARMONICS LEVELS IN dBmV AT AMPLIFIER OUTPUT

$L2a = K_2 + 2\,La - 6, \text{ at } 2\,f_a$

$L2b = K_2 + 2\,Lb - 6, \text{ at } 2\,f_b$

$L2c = K_2 + 2\,Lc - 6, \text{ at } 2\,f_c$

where

k_1 and k_2 are constants. They are complex numbers describing the first and second order gain, phase shift and distortion properties of the amplifier. To permit easy mathematical development consider them to be constant for all input signal frequencies. Measurement on practical amplifiers prove that in reality this is not the case and care must be exercised before drawing conclusions concerning real amplifiers from the mathematical considerations.

K_2 is a decibel constant characterizing second order distortion.

$$K_2 = 20 \operatorname{Log} \frac{\dfrac{k_2}{\sqrt{2}}}{\left(\dfrac{k_1}{\sqrt{2}}\right)^2}$$ expressed in dBmV

Lab, Lbc, Lac = Sum and difference beats in dBmV

$L2_a$, $L2_b$, $L2_c$ = Second order harmonics in dBmV

La, Lb, Lc = First order output levels in dBmV

f_a, f_b, f_c = Corresponding frequencies

When you read a amplifier specification sheet the information you should be concerned with is listed in these terms Second Order = -66 dB at + 50 dBmV output. The equipment supplier is saying the following, (at +50 dBmV output, when operated within the recommended operating parameters i.e. slope, gain, tilt, etc. this amplifier will not produce a second order component that will not be less than 66 dB below the nearest carrier).

The trunkline amplifier is typically not operated at +50 dBmV output. If you operate the amplifier at +30 dBmV output the amplifier deration for second order will be 50 - 30 = 20 dB, and -66 - 20 = - 86 dB second order for this amplifier. When you have a cascade of 32 amplifiers identical to this amplifier you can expect the second order to increase 3 dB each time you double the cascade of 1, 2, 4, 8, 16, 32 is equal to five doubles. The expected second order will then be -86 + 15 = 71 dB below the nearest carrier. When the amplifier station is not a direct double subtract (dB - 10 Log_{10} N), from -86 where N = the number of amplifiers in cascade.

The above information will allow you to determine the level of second order you should expect. The remainder of the article will clarify the methods of measurement and the analysis of the results.

Figure 1 is a spectrum analyzer view of the new sum and difference components generated when two first order components are introduced to an amplifier with second order distortion. Note that in addition to the two original carriers, there are four additional new components. These are the sum and difference beats of F_1 and F_2 plus the second harmonics of F_1 and F_2.

Figure 2 applies the basic knowledge of figure 1 to a CATV system. The difference of channel 2 carrier and channel 6 carrier is 28 MHz. The second harmonic of channel 4 carrier is 134.5 MHz or channel C in the midband. Channel 8 carrier minus channel 2 carrier = 126 MHz. When the VHF carrier frequencies were assigned the second order problem was recognized and with the exception of channel 6 sound carrier (the second harmonic is 175.5 or channel 7) the 12 channel systems do not fall prey to second order distortion.

The addition of the mid and super-band channels increases the total number of beat products to a point of mass congestion.

Channel 13 - 2 = 156 MHz
Channel J - 3 = 156 MHz
Channel K - 4 = 156 MHz

The measurement of a singular second order product is increased in difficulty if you need to worry about additional products that may cloud the final results. Remove all carriers from the system with the exception of the contributing carriers and system support carriers, i.e. slope and gain control carriers, plus carriers adjacent to support carriers if necessary due to slope or gain dependency resulting from inadequate pre-selection in the amplifier circuitry.

Figure 3 depicts some carriers that may be used for the measurement. The basic reason these carriers were selected was due to their position within the passband. There is one low, one mid and one high. The worst case condition for second order distortion is usually a high minus a low falling into a mid band channel.

Channel 13 - 2 = 156 MHz. The second order beat will usually fall within 20 kc of 156 MHz depending upon the exact frequencies of channels 2 and 13. The beat will be 1.25 MHz below channel G visual carrier plus or minus the above mentioned 20 kc and any channel G deviation from standard frequency.

Figure 3 is representative of the results you would obtain with a spectrum analyzer with 70 dB dynamic range. The spectrum analyzer reads peak amplitude and the readout is directly in dB. This figure illustrates a second order product at 156 MHz. The product is 50 dB below the G carrier peak amplitude. The product at 110.5 MHz is the second harmonic of channel 2. Second harmonics are typically six dB less than sum and difference beats.

Figure 4 outlines the equipment setup.

The spectrum analyzer approach is the easiest method to measure second order. The three drawbacks to this approach are:

1. Cost
2. Portability
3. Measurement sensitivity

If you have ever priced a spectrum analyzer with a 70 dB dynamic range the first drawback is self-explanatory. If you plan to fly and check the unit as baggage, leave the office early, pack an extra tube of Ben Gay ointment and make sure your company carries insurance. This is due to the fact that the airlines will not accept liability in excess of $500.00 unless you ship it air freight.

Last and possibly least is the measurement sensitivity. The sensitivity crossover point in a typical system is 16 to 20 amplifiers in cascade. Prior to this point, the distortion will be undetectable.

WAVE ANALYZER APPROACH

When you select an alternate assignment of measurement carriers, the equipment costs are reduced to a more acceptable pricetag. The change involved is related to the channel G carrier. The frequency is shifted from 157.25 MHz to 156.00 MHz. The exact carrier frequency is trimmed up or down the required amount to place the second order beat at G carrier ± 5 kc. The second order beat will now become a channel G sideband displaced by 5 kc with an amplitude relationship to the G carrier equal to the differential in level.

The spectrum analyzer method allows a simultaneous view of the carrier amplitude and the second order beat amplitude which yields a simple interpretation of information. This advantage is not the case with the wave analyzer approach, which leads us to the calibrator that is necessary to establish the reference level required for the measurement by comparison technique.

Fig. 5

The calibrator R.F. input is derived from a standard V.H.F. signal generator tuned to 156 MHz. The switcher is driven by a variable rate generator. When the second order beat is 5 kc removed from the 156 MHz carrier the rate generator will then switch the R.F. carrier between the test and reference leg of the switcher at 5 kc rate. When you add 40 dB attenuation in the reference leg the switcher output will alternate between a test level and a reference level 40 dB down.

The output of the switcher is connected to a field strength meter. The field strength meter is tuned to the 156 MHz carrier and the manual gain of the meter is adjusted for +4 volts DC on the voltmeter.

Tune the wave analyzer to 5 kc. The indication on the meter at 5 kc will be the calibration reference. The reference will be 40 dB down from the 156 MHz carrier. Note the meter reading in terms of the number of dB's the indication deviates from full scale deflection.

When the above has been accomplished the system second order may be measured by changing the F.S.M. input lead from the switcher to the channel G bandpass filter that is connected to the system testpoint.

Procedure:

1. Check F.S.M. tuning and retune to 156 MHz if necessary.

2. Adjust manual gain for +4 volts DC on the meter.

3. Remove 30 dB attenuation from the wave analyzer and tune for maximum indication. The beat may not be exactly 5 kc due to instability of the contributing carrier generators.

4. The sum total of the -40 dB reference plus the amount of attenuation removed from the analyzer plus or minus the meter reading deviation from reference, equals the level of the second order component.

The second method of calibration is more difficult but utilizes equipment that is common and readily available. Fig. 6 illustrates the equipment and the procedure is as follows:

1. Remove the 40 dB pad.

2. Adjust the F.S.M. tuning to 156 MHz.

3. Remove output lead from Gen # 2.

4. Tune Gen # 1 to 156 MHz and adjust level to "0" dBmV.

5. Remove the output lead from Gen # 1.

6. Reconnect the Gen # 2 output lead.

7. Tune Gen # 2 to 156.00 MHz and adjust level to "0" dBmV.

8. Reconnect Gen #1 output load.

9. Tune wave analyzer to 5 kc and make a fine adjustment on the frequency of Gen #2 until the wave analyzer reading peaks, indicating a 5 kc difference between the two signals.

10. Add the 40 dB pad to the output lead of Gen #2.

11. Retune the F.S.M. for peak reading on voltmeter.

The above results in a 5 kc sideband 40 dB down. The remainder of the procedure follows the outline presented for the first calibration and measurement method.

This measurement of second order distortion is not difficult when you have proper instrumentation, however I will list a few of the areas that may introduce errors in the reading.

A. Remember to maintain a good match at the amplifier output port. Never let the amplifier look directly into a field strength meter. When the measurement is made on equipment that does not utilize an attenuation test probe, or at least a 10 dB down testpoint, be sure to isolate the output match by installing a 10 dB pad directly on the output of the amplifier.

B. The bandpass filter at the input to the field strength meter or spectrum analyzer will prevent the generation of second order in the measurement receivers.

C. The calibration procedure at 5 kc is not correct for any other frequency unless you are sure the wave analyzer has a flat response to all frequencies. Check the response periodically with an audio oscillator of known flatness across the measurement frequencies.

FIG. 1

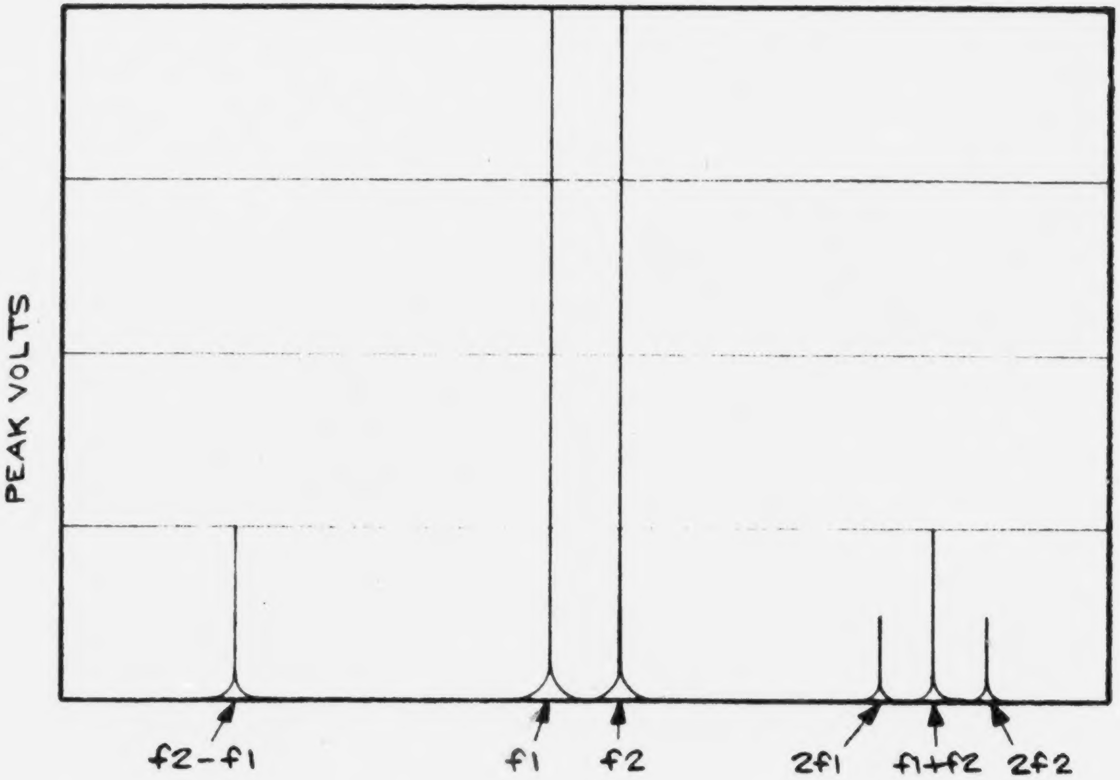
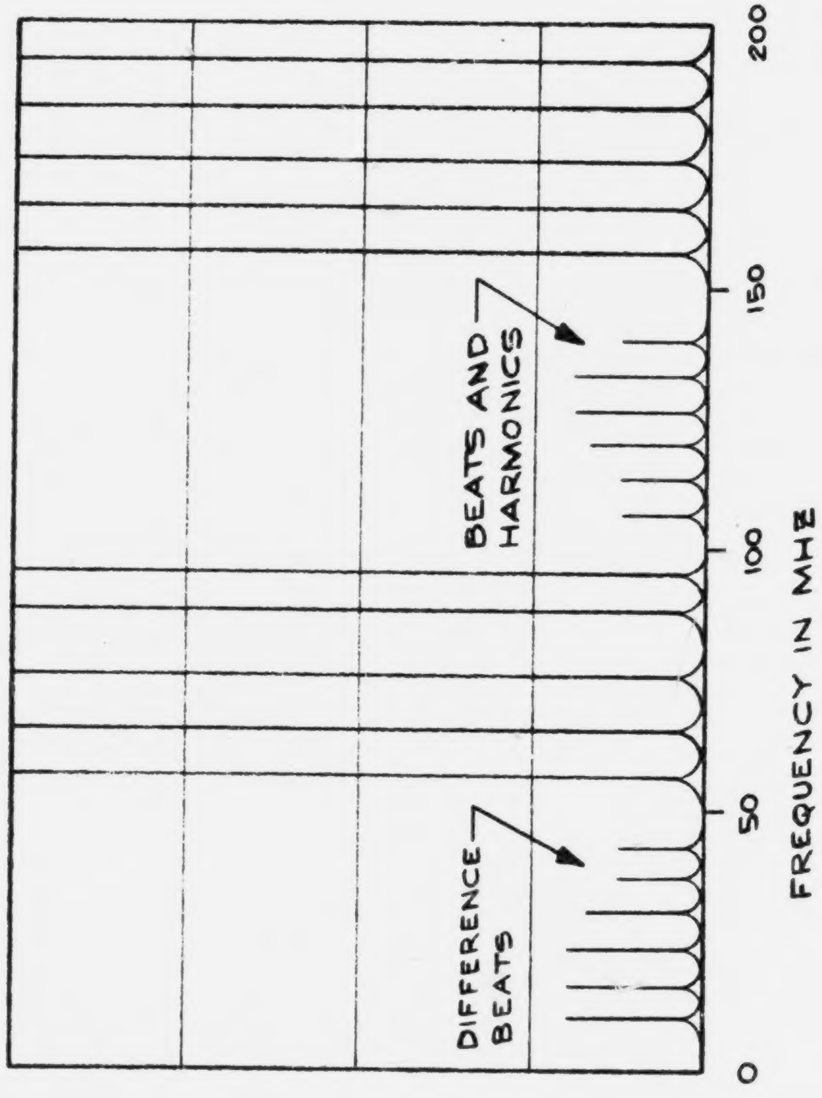


FIG.2


DIFFERENCE BEATS
BEATS AND HARMONICS
0
50
100
150
200
FREQUENCY IN MHZ

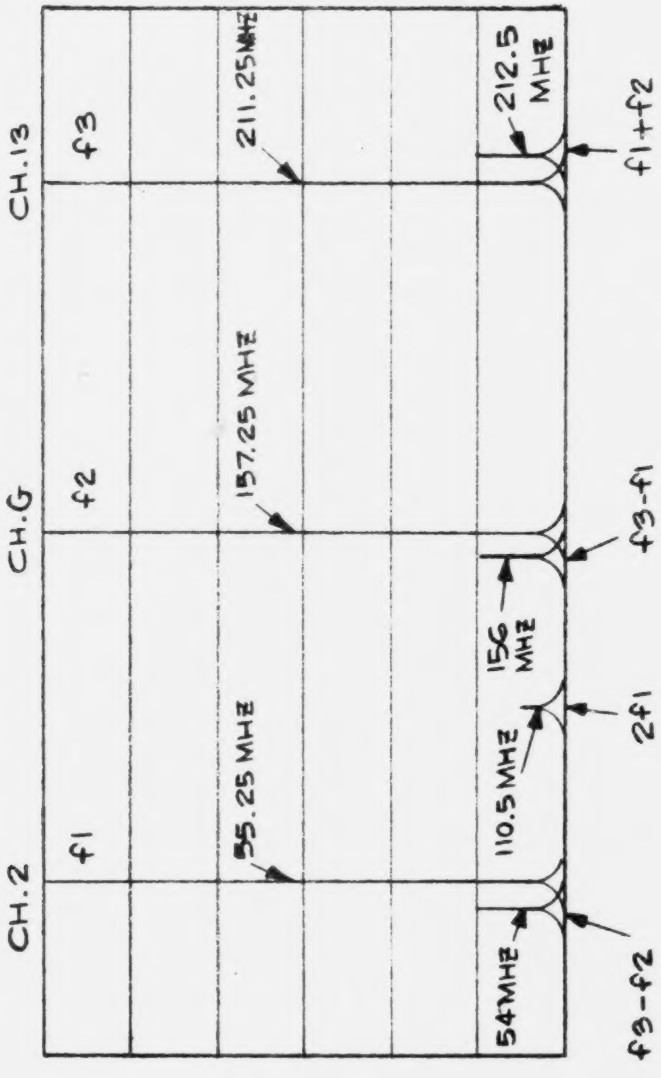
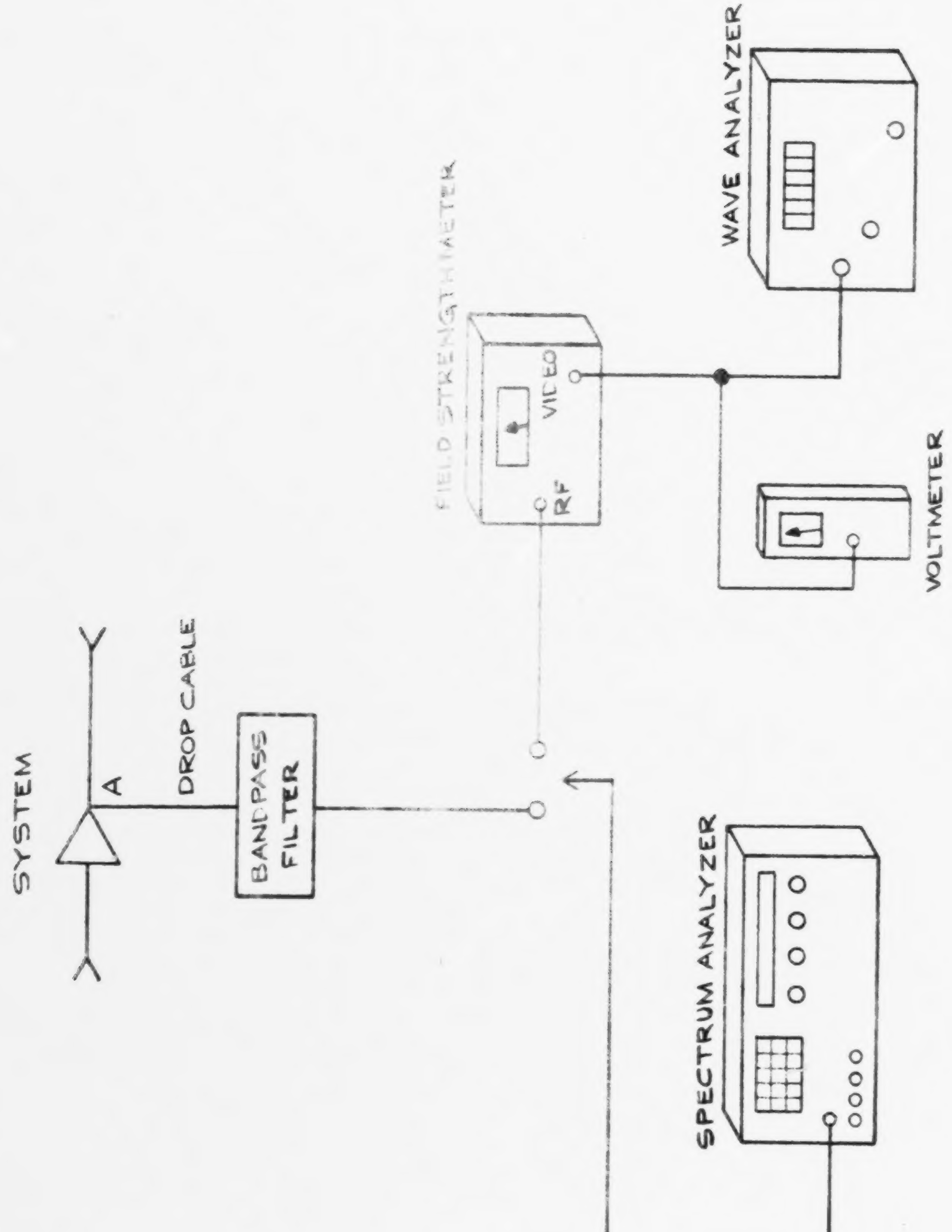

CH.2
f1
55.25 MHZ
54MHZ
f3-f2
110.5 MHZ
2f1
156 MHZ
CH.G
f2
157.25 MHZ
f3-f1
CH.13
f3
211.25 MHZ
212.5 MHZ
f1+f2

FIG. 3

SECOND ORDER

FIG. 4


SYSTEM
A
DROP CABLE
BANDPASS FILTER
FIELD STRENGTH METER
RF
VIDEO
VOLTMETER
WAVE ANALYZER
SPECTRUM ANALYZER

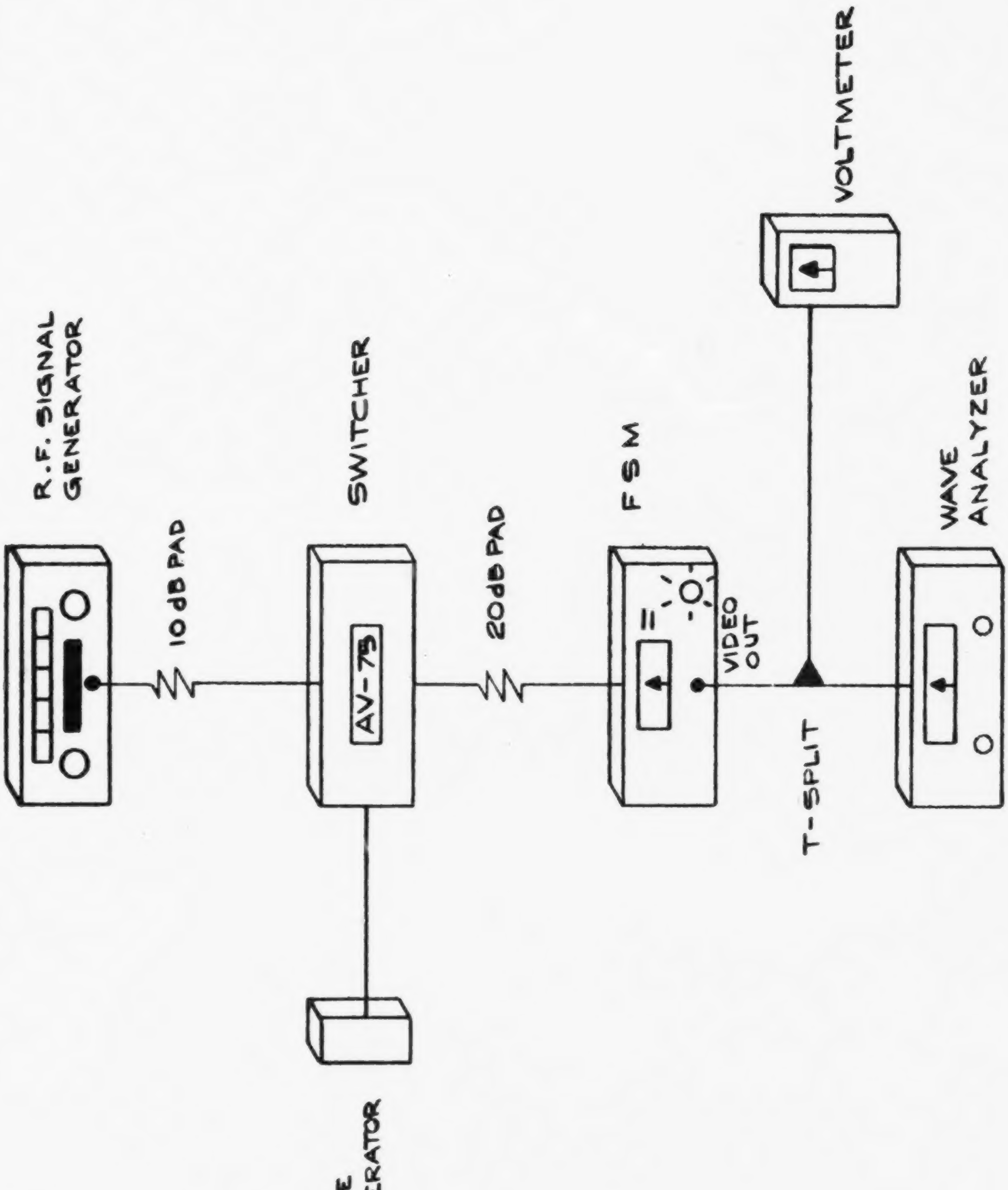

R.F. SIGNAL GENERATOR
10dB PAD
SWITCHER
AV-75
RATE GENERATOR
20dB PAD
F S M
VIDEO OUT
T-SPLIT
VOLTMETER
WAVE ANALYZER

FIG. 5

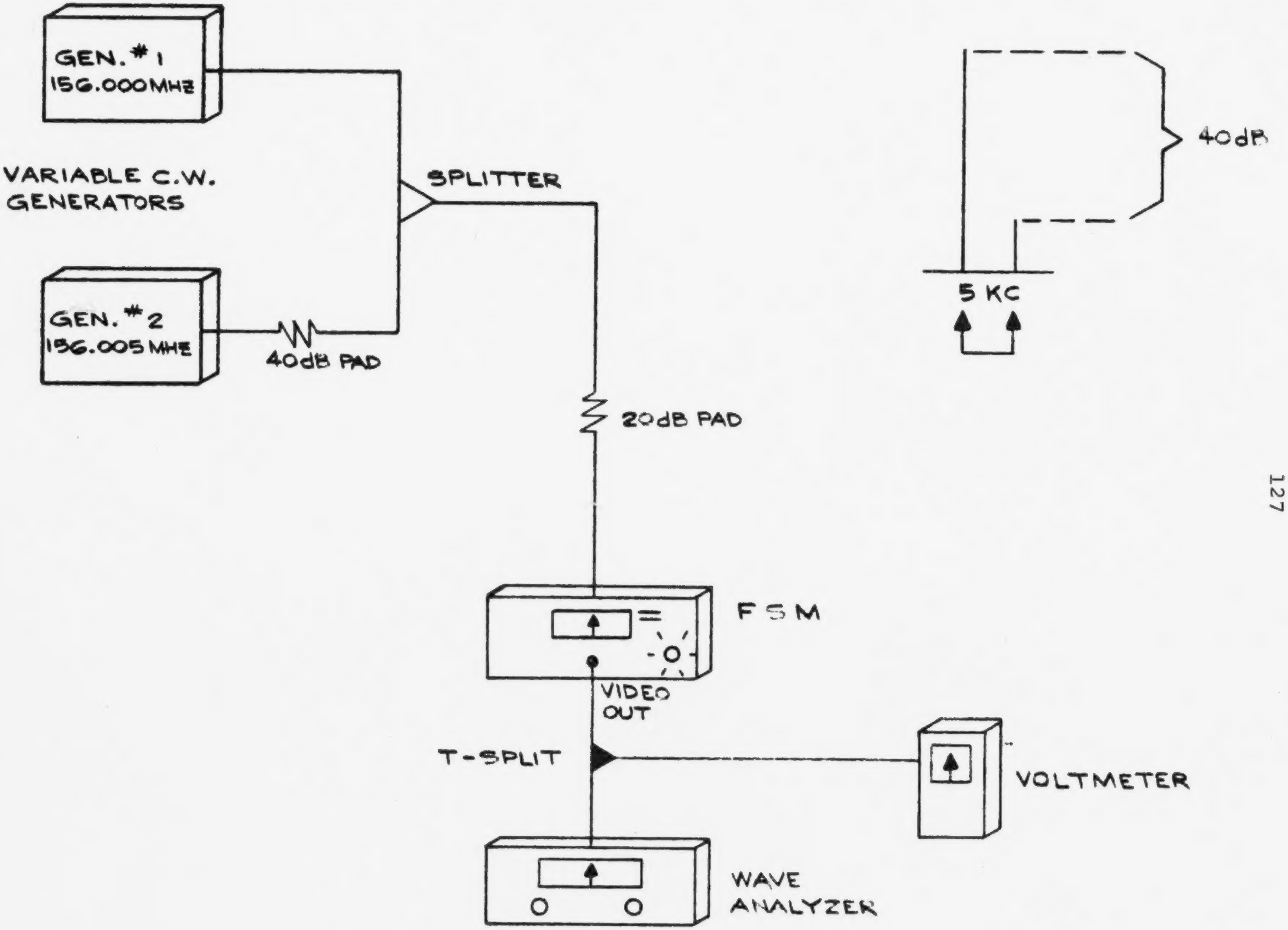

GEN. #1
156.000 MHz
VARIABLE C.W.
GENERATORS
GEN. #2
156.005 MHz
40dB PAD
SPLITTER
20dB PAD
5 KC
40dB
FSM
VIDEO
OUT
T-SPLIT
VOLTMETER
WAVE
ANALYZER

FIG. 6

The measurement techniques outlined on the preceeding pages have been tried and proven. The theory is sound and the procedures lend themselves readily to field application. With a few minor changes in calibration the wave analyzer can measure any coherent product such as triple beat, intermodulation and cross modulation.

TRIPLE BEAT

Triple beat may be measured by using the same procedure that was used for second order measurements. Fig. 7 illustrates the measurement carriers. Since all the visual carriers are separated by 6 MHz the triple beat component will fall back on the carrier plus or minus the offset in frequency due to instability of the carrier generators.

The calibration procedure is the same as was used to calibrate for second order. The frequency of the R.F. source is not important because the front end of the F.S.M. does not require calibration. It is only the detector and the associated linearity that is a variable.

When you have completed the 40 dB down calibration you may proceed with the measurement.

1. Remove all carriers from the system except channels 9, 10, 11, 12 and pilot carriers.

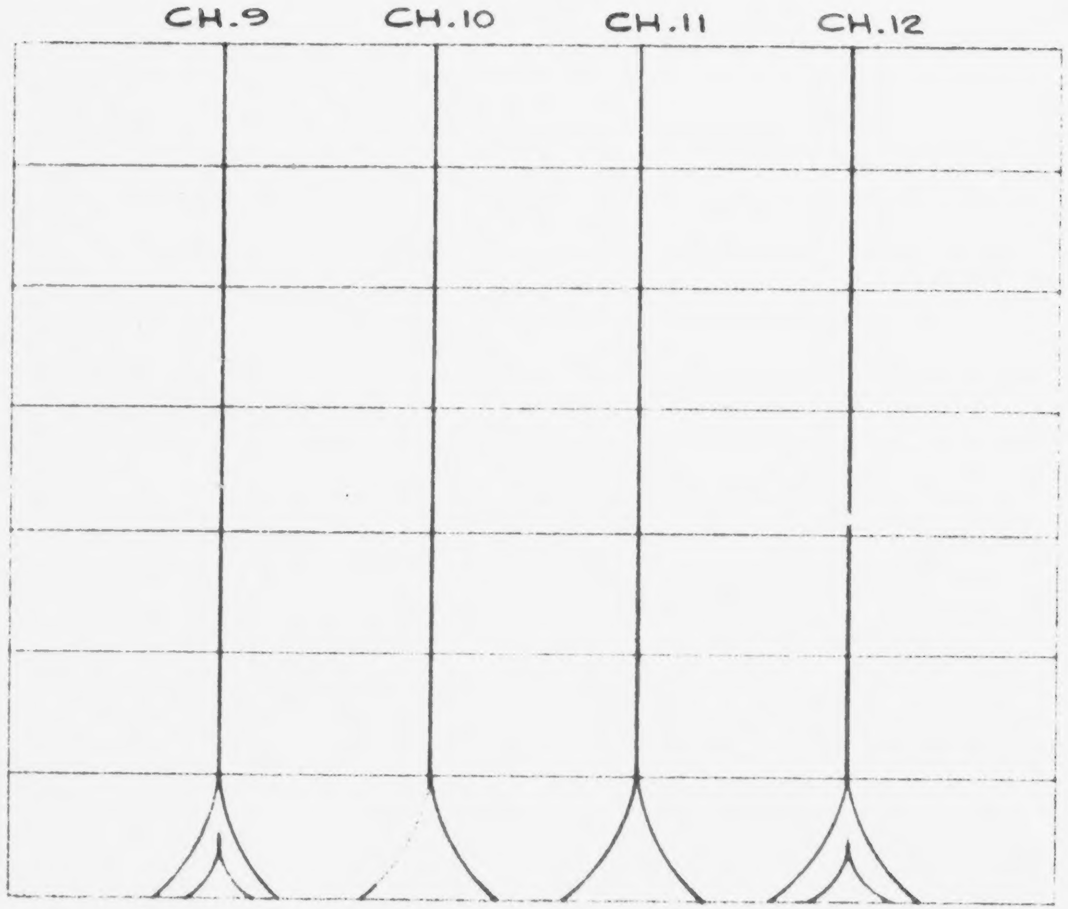
2. Connect the receiver to the system via a channel 9 bandpass filter.

3. Tune the F.S.M. to channel 9 and adjust the manual gain to +4 volts at the F.S.M. video output.

4. Remove 40 dB of attenuation from the wave analyzer and tune the analyzer for maximum indication.

   There will be two beat components (1) triple beat (2) inter-mod. The inter-mod will be 6 dB lower in level than the triple beat. The inter-mod is due to 2 X 10 - 11 and will be at a different frequency because channel 12 is not involved. Tune for the component that is higher in level.

TRIPLE BEAT


CH.9
CH.10
CH.11
CH.12

10 + 11 − 12 = 9
10 + 11 − 9 = 12

193.25 + 199.25 − 205.25 = 187.25
193.25 + 199.25 − 187.25 = 205.25

FIG. 7

5. The sum total of the -40 dB reference plus the amount of attenuation removed from the analyzer plus or minus the meter reading deviation from reference, equals the level of the triple beat.

It may be desireable to perform a reference test at the head-end. This will yield an indication of the probable beat frequency and prove the validity of the field measurements.

Remove all carriers except 9, 10, 11, 12 and pilot carriers. Connect the head-end trunk cable to a line extender, adjust the output level to +50 dBmV. Insert a variable attenuator on the output and reduce the level to "0" dBmV. Connect the receiver to the variable attenuator via a bandpass filter tuned to the measurement frequency.

The reference measurement may now be made. Alternately removing carriers will verify that you are measuring the desired triple beat component. The field measurement will be at approximately the same frequency but will vary as a function of processor stability.

CROSS MODULATION

Cross modulation is the transfer or "crossing" of modulation from the interferring channel to the desired channel, resulting in a weak reproduction of the picture that the interferring channel super-imposed on the picture being viewed. Since the receiver's horizontal scanning is synchronized with the wanted signal but usually not with the interferring one. The two horizontal frequencies usually differ slightly and the interferring picture moves back and forth across the screen reproducing slanting bars which give the windshield wiper effect.

Since it is difficult to measure cross-modulation on the wanted channel, this measurement has usually been done with a CW signal substituted for the wanted picture signal. Where cross modulation exists, it results in a variation in the peak voltage of an otherwise unmodulated signal substituted for the wanted carrier. Percent cross-modulation is defined as 100 times the ratio of this variation to the maximum peak voltage.

The equipment required to measure cross-modulation will consist of a transmitting and a receiving package. The most desirable transmitting package is a multi-carrier signal generator. Output frequencies corresponding to the standard VHF channel assignments plus additional mid, sub and super-band frequencies. This head-end substitution transmitter must also contain individual modulators for each carrier and a two position switch for choosing either CW or modulated carrier. It is also very desirable if the unit possess individual carrier level control.

If you desire to buy a transmitter remember the old saying, "haste makes waste." Transmitters on the market today range from $7,000 to $14,000, and you should attempt to squeeze every ounce of return from your investment.

First of all consider the variety of testing you will be performing and which frequencies will be involved. Second order, channels 2, G, 13, T7, T8, and T9. Triple beat, channels 9, 10, 11, 12, T8, T9, T10 and a 30 MHz carrier. Carrier-to-noise channels 2, 13, 0, T7 and T10. Group delay, channels 2, 3, 13, T10 and 30 MHz. Automatic slope channels 4 and 11. AGC depends upon your system pilot carrier frequency.

The total channels in numerical order are T7, T8, T9, T10, 30 MHz, 2,3,4, pilot carrier, G, 9, 10, 11, 12, 13 and 0. Total number of channels is 16. Since the generators are usually built to order you can select the frequencies you desire. Remember that the measurement of second order with the wave analyzer requires that the beat falls within a few kc of the measurement carrier. Therefore channel T7 should be 6 MHz, T8 12 MHz, T9 18 MHz, T10 24 MHz and channel G 156 MHz.

The initial cost of the transmitter is far outweighed by the advantages it offers. The following is a partial list:

1. Due to the fact that the system service must be interrupted for cross-mod testing,the available testing time is limited to two or three hours of early morning work. Time then becomes a very important commodity and efficiency is the word of the day. The carrier generator will allow you to reduce the equipment set-up time in the head-end by a factor of 10, which allows you more time for system testing.

2. Since the head-end remains basically intact you do not run the risk of head-end equipment malfunction due to re-arrangement of processor operating parameters and levels.

3. If you have ever desired to build a independent lab for evaluating products, this unit is definitely for you.

Figure 8.a. depicts the second method which requires a processor that has provisions for modulating the internal standby carrier. Some processors have terminal strips that will accept baseband information and produce an output that is modulated at the aforementioned baseband frequency. If your processor does not have this capability you may be able to use a alternate method depending upon the availability of a 45.75 MHz I.F. tie point. The sequence is outlined by figure 8.b. and the following procedure:

An audio frequency generator with a 15,750 Hz square wave output is utilized to modulate a modulator at 100%. The frequency is relatively unimportant but it can serve as one of the modulated carriers. A sample output can serve as the input to a processor, whouse output in turn would serve as the second modulated carrier. The processor I. F. module output then can be sampled with a directional coupler and the processor output level re-established with the coupler insertion loss in place.

The sample signal at the I.F. frequency is then divided equally and inserted at the input of the I.F. amplifier in each of the remaining channel processors. All of the outputs including the CW outputs which are established by the signal replacer of the desired test channels should be operated at normal system levels.

Before leaving the head-end you should always make a reference cross-modulation measurement to assure the receiving package is in good working order. Normally the measurement will be very low and will be noise limited in the range of -90 to -100 dB.

Referring to figure 4 for receiving point test set-up the measurement is accomplished as follows:

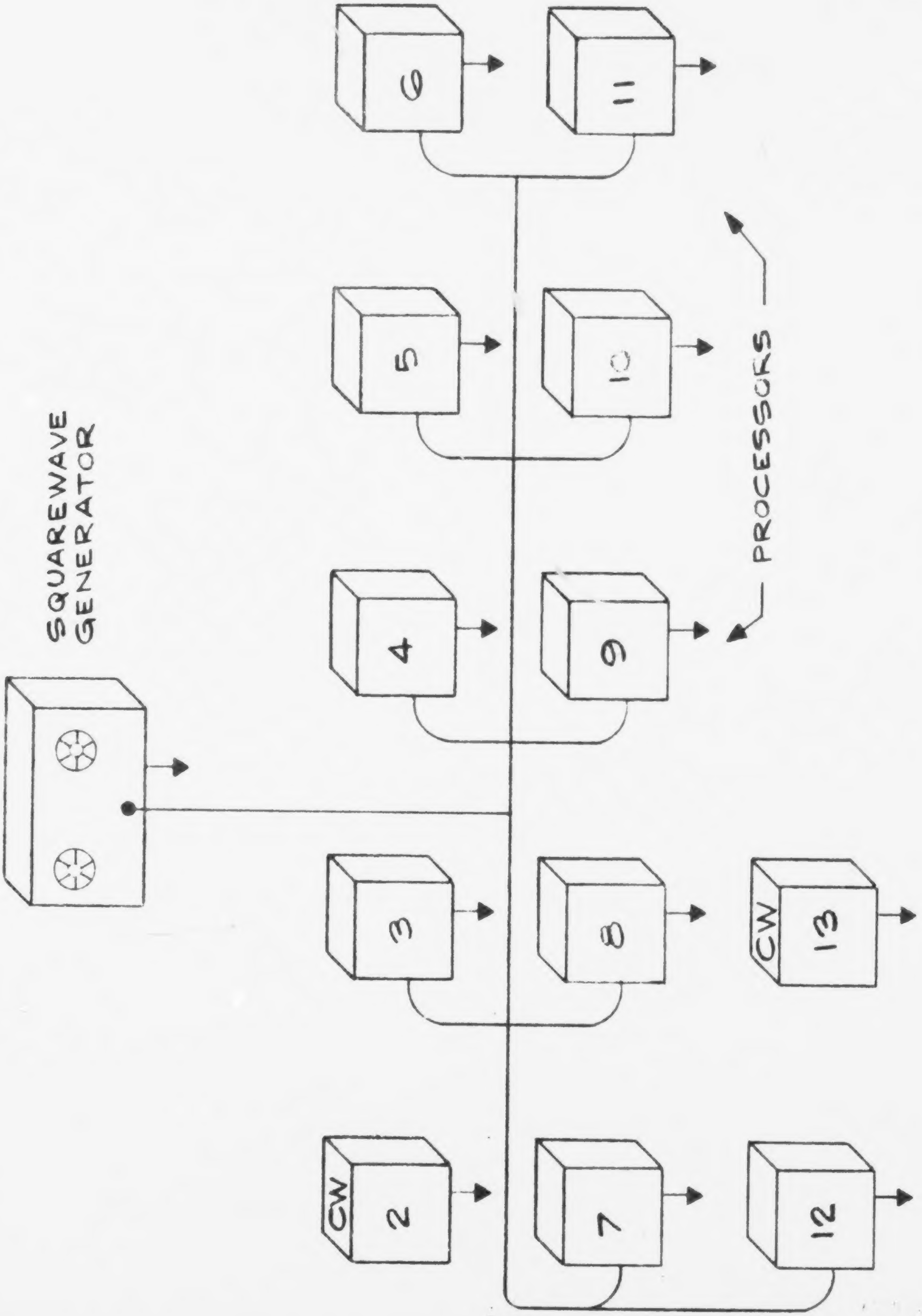
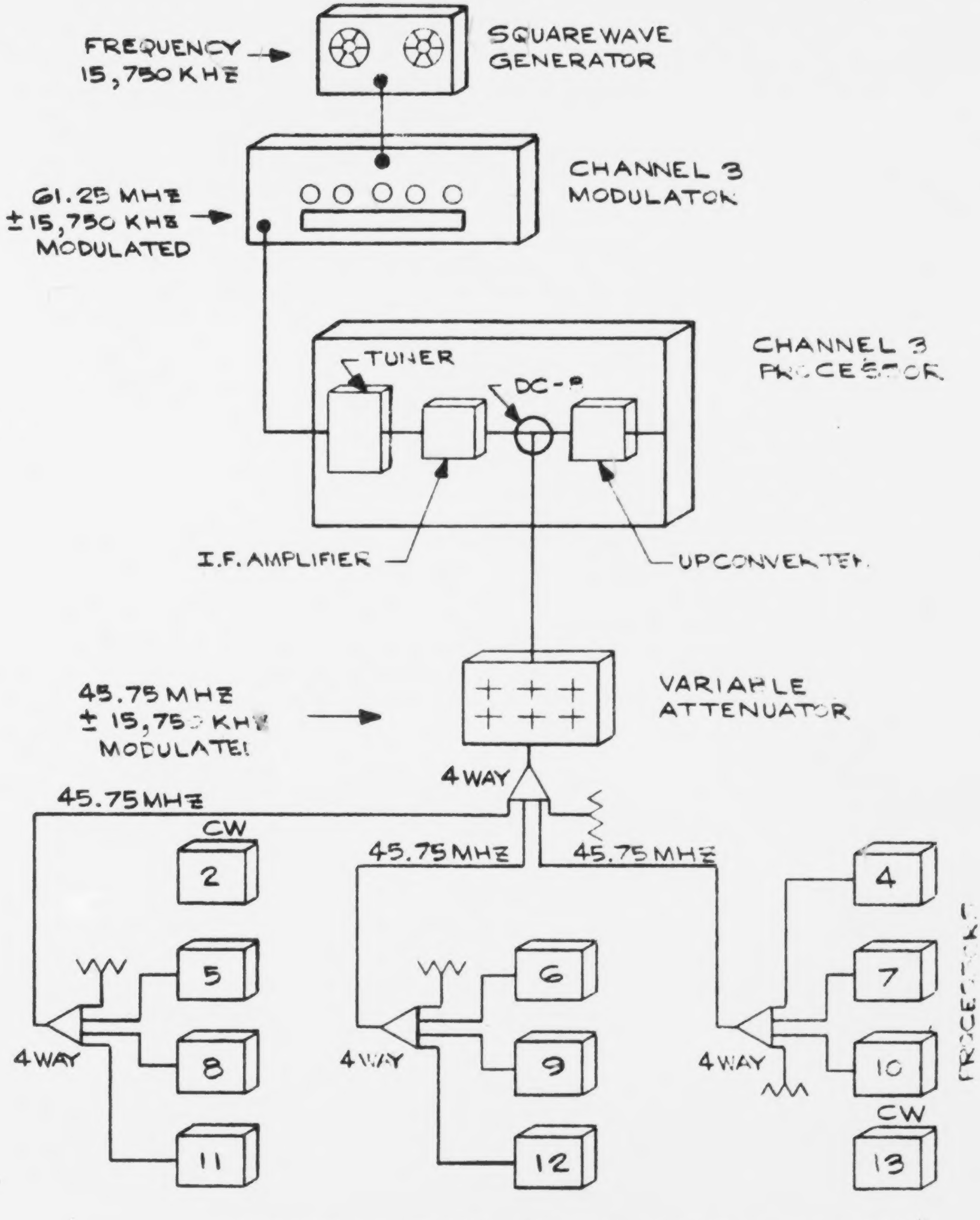

SQUAREWAVE GENERATOR
PROCESSORS
CW
2
3
4
5
6
7
8
9
10
11
12
CW
13

FIG.8A


FREQUENCY 15,750 KHZ
SQUAREWAVE GENERATOR
61.25 MHZ ± 15,750 KHZ MODULATED
CHANNEL 3 MODULATOR
CHANNEL 3 PROCESSOR
TUNER
DC-8
I.F. AMPLIFIER
UPCONVERTER
45.75 MHZ ± 15,750 KHZ MODULATED
VARIABLE ATTENUATOR
4 WAY
45.75 MHZ
45.75 MHZ
45.75 MHZ
CW
2
5
8
11
4 WAY
6
9
12
4 WAY
4
7
10
4 WAY
CW
13
PROCESSORS

INSERT 45.75 MHZ "SQUARE WAVE MODULATED" AT INPUT TO I.F. AMPLIFIER

FIG. 8B

a. Develop a 40 dB down reference reading on the wave analyzer by utilizing the calibrator in the manner outlined in the section of this paper titled Second Order Measurements. The calibration procedure for cross modulation is slightly different than in the case of second order and triple beat. The attenuator should be adjusted for 44 dB of attenuation due to the differences of sine wave and square wave modulation. This amount of attenuation will develop a reference that is 40 dB down from carrier. When the calibration procedure is complete continue with these outlined procedures.

b. Connect the system testpoint to the input of the bandpass filter that is tuned to the measurement channel. Connect the output of the bandpass filter to the input of the field strength meter. Tune the field strength meter to the desired measurement channel and increase the field strength meter gain until the voltmeter indicates +4 VDC.

c. Tune the wave analyzer frequency control to obtain maximum deflection at 15,750 Hz. (This may require the removal in steps of 10 until a useable scale indication is reached on the wave analyzer meter). The direct reading of cross modulation, (in dB) imposed on the CW carrier by the presence of the modulated carriers will be equal to the sum of 40 dB reference, plus the attenuation removed from the wave analyzer attenuator, ± the final deflection of the meter from reference setting.

d. Refer to the chart enclosed to translate this cross modulation to the system channel capability by adding or subtracting the indicated amount to the reading.

SYSTEM RADIATION

System radiation shall be limited as follows:

Up to and including 54 MHz, 15 microvolts per meter at 100 ft. From 54 to 216 MHz, 20 microvolts per meter at 10 ft. Over 216 MHz, 15 microvolts per meter at 100 ft.

It is difficult to measure 20 microvolts per meter utilizing a tuned half wave dipole and the standard field strength meter.

To clarify the point, assume that the cable system is radiating 20 microvolts per meter at 10 ft. on channel 12. If this is the case the standard field strength meter connected to the output of the dipole antenna must be capable of measuring a -46 dBmV. This is not practical with the standard field strength meter. However, you may make the situation slightly more tolerable by adding a preamplifier between the dipole antenna and the field strength meter and the level will be within the sensitivity range.

The additional noise from the field strength meter due to the low input level will further obscrure the reading when the measurement is attempted. At 300 MHz, expect the carrier-to-noise to degrade by an additional 3.3 dB. When the measurement is made at channel 2 expect the carrier to noise to improve by 11.3 dB.

In summation the technique is useable for frequencies up to 100 MHz, but for frequencies higher than 100 MHz the results would be questionable. The aforemention analysis is predicated on the assumption that the field intensity of cosmic noise, atmospheric noise, and man-made noise is not excessive.

Unfortunately the median value of both urband and suburban man-made noise is in excess of 10 microvolts per meter when measured with a 600 kc bandwidth field strength meter. The facts at this point indicate that the field strength meter is not the receiving instrumentation necessary to measure such low values of radiation.

However these low values can be measured if we utilized the spectrum analyzer. The spectrum analyzer can perform the measurement for two basic reasons. Increased sensitivity and the ability to reduce the receiver bandwidth to the point that noise is not objectionable.

CARRIER-TO-NOISE

The average field strength meter is designed to measure the voltage and the dBmV levels of CW, FM carriers and television signals in cable systems. Although it is not calibrated for noise levels, with suitable correction, a meter can be used for this purpose.

Two factors prevent it from reading noise levels directly and both must be taken into account in the correction. One source of error is in the bandwidth of the average field strength meter which is approximately .6 MHz. Since noise power is proportional to bandwidth, the apparent noise will be reduced by a factor of 8.2 dB, which is the decibel equivalent of a power ratio of 4 MHz divided by .6 MHz. The second error occurs in the opposite direction. It is due to the fact that the average field strength meter utilizes a peak detector. Peak detectors will attempt to respond to the noise peak better than reading the RMS noise. Since noise has a higher peak to RMS ratio than the CW signals the detected output reads high. As its output is reduced the efficiency of the detector is lowered and reads closer to RMS so more total correction is needed at the low end of the meter scale.

Figure 9 illustrates the maximum, average and minimum correction values dependent upon the needle position on the dBmV scale of the field strength meter. The appropriate correction corresponding to the needle position on the scale is then added to the measured level to obtain true noise level.

TEST DESCRIPTION

The carrier-to-noise ratio should be measured utilizing the lowest and highest carrier frequency transported by the transmission system. These frequencies should generally be considered to be the worst cases if the system frequency response is held within ± 3 dB. The carriers shall be generated by the head-end processing equipment and the receiver package shall consist of one variable attenuator and one field strength meter. Previously mentioned field strength meter correction factors can be verified by measuring any known noise source, but this is usually not essential.

TEST PROCEDURE

A. Connect a drop cable from the system testpoint to the input of variable attenuator.

B. Connect the output of the variable attenuator to a bandpass filter that is tuned to the measurement channel.

C. Connect the output of the bandpass filter to the RF input of the field strength meter.

D. Insert 60 dB of attenuation in the variable attenuator; operate the field strength meter at the range required to obtain a meter deflection of 0 dBmV on the scale when tuned to the measurement carrier.

E. Remove the measurement carrier from the transmission system.

F. Remove attenuation from the variable attenuator until the meter deflection returns to 0 dBmV output on the scale.

G. Tune the field strength meter plus or minus 1 MHz and null the meter reading.

H. Remove attenuation from the variable attenuator until the meter indication returns to 0 dBmV on the scale.

I. Note the total amount of attenuation removed, this indicates the uncorrected carrier-to-noise ratio.

J. Subtract the 4.2 from the above curve for the true carrier-to-noise ratio.

There are a few procedures that must be followed to insure that the measurements are accurate. Step G indicates that the field strength meter tuning should be moved above and below the carrier in search of a null. The reason for this becomes quite apparent when we attempt to measure the carrier-to-noise in the feeder system.

When channel 13 is used as the referenced carrier for noise measurements there will be a discrepancy in the reading due to the addition of triple beat. A 12 carrier CATV system will produce 13 triple beats that fall directly on channel 13 plus or minus the frequency stability and their respective output converters.

The noise level measured when channel 13 is removed is equal to the noise plus 13 triple beat components that fall within the field strength meter passband.

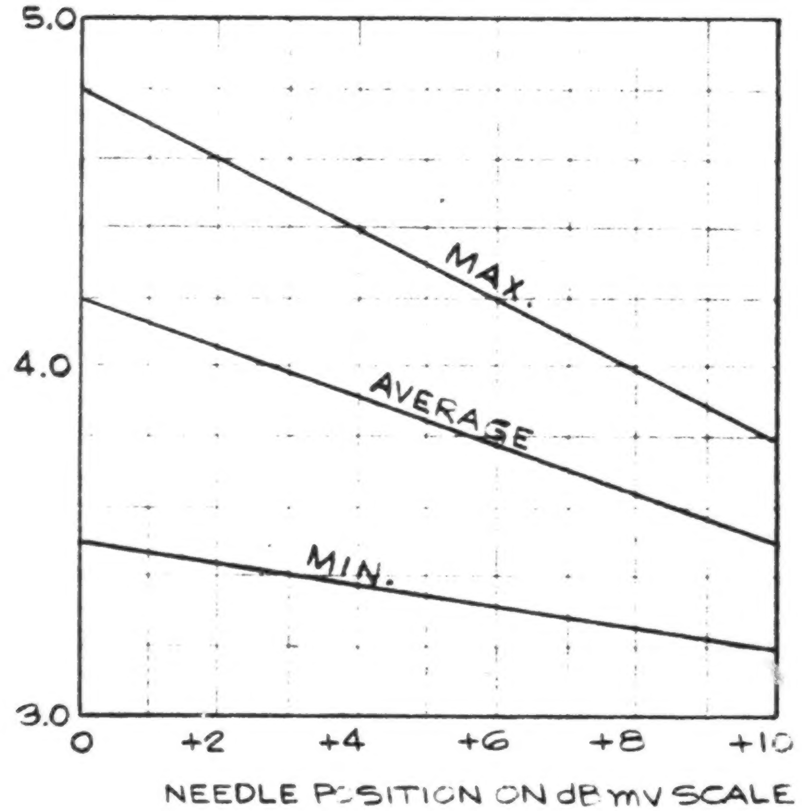

5.0
4.0
3.0
CORRECTION-dB
MAX.
AVERAGE
MIN.
0
+2
+4
+6
+8
+10
NEEDLE POSITION ON dBmV SCALE

FIG.9

The de-tuning of the field strength meter will result in some relief due to triple beat interference. It would be advantageous to remove all the carriers from the system except the pilot carrier, slope carriers, and carriers adjacent to these control carriers. The bandpass filter preceding the field strength meter is required basically to reduce any possible beat combinations within the meter.

In the attempt to measure a 50 dB carrier-to-noise ratio care must be taken not to introduce errors due to the selectivity of the field strength meter. The channels adjacent to the measure carrier should be removed from the system to prevent adjacent channel addition to the noise.

CARRIER TO HUM

Since most CATV amplifiers are powered from a 60 cycle AC source there will always be some value of power supply ripple on the DC supplies. This ripple will modulate the signal going through the amplifier. Hum modulation will appear on the television receiver as horizontal bars that move up or down, so it is necessary to test amplifiers and systems to insure that this effect is not objectionable.

The test procedure for determining the percentage of hum modulation is as follows:

1. Assemble the test equipment as shown in figure 10.

2. Connect the system test point to the RF input of the field strength meter.

3. Tune the field strength meter to any CW signal present on the system including the pilot carrier. When the system utilizes automatic slope amplifiers that are tuned to a modulated carrier you will be required to introduce a hum free source of CW at the system origination point.

4. Sync the oscilloscope to the "line" at a frequency of 30 or 60 cycles.

5. Adjust the oscilloscope coupling to D.C.

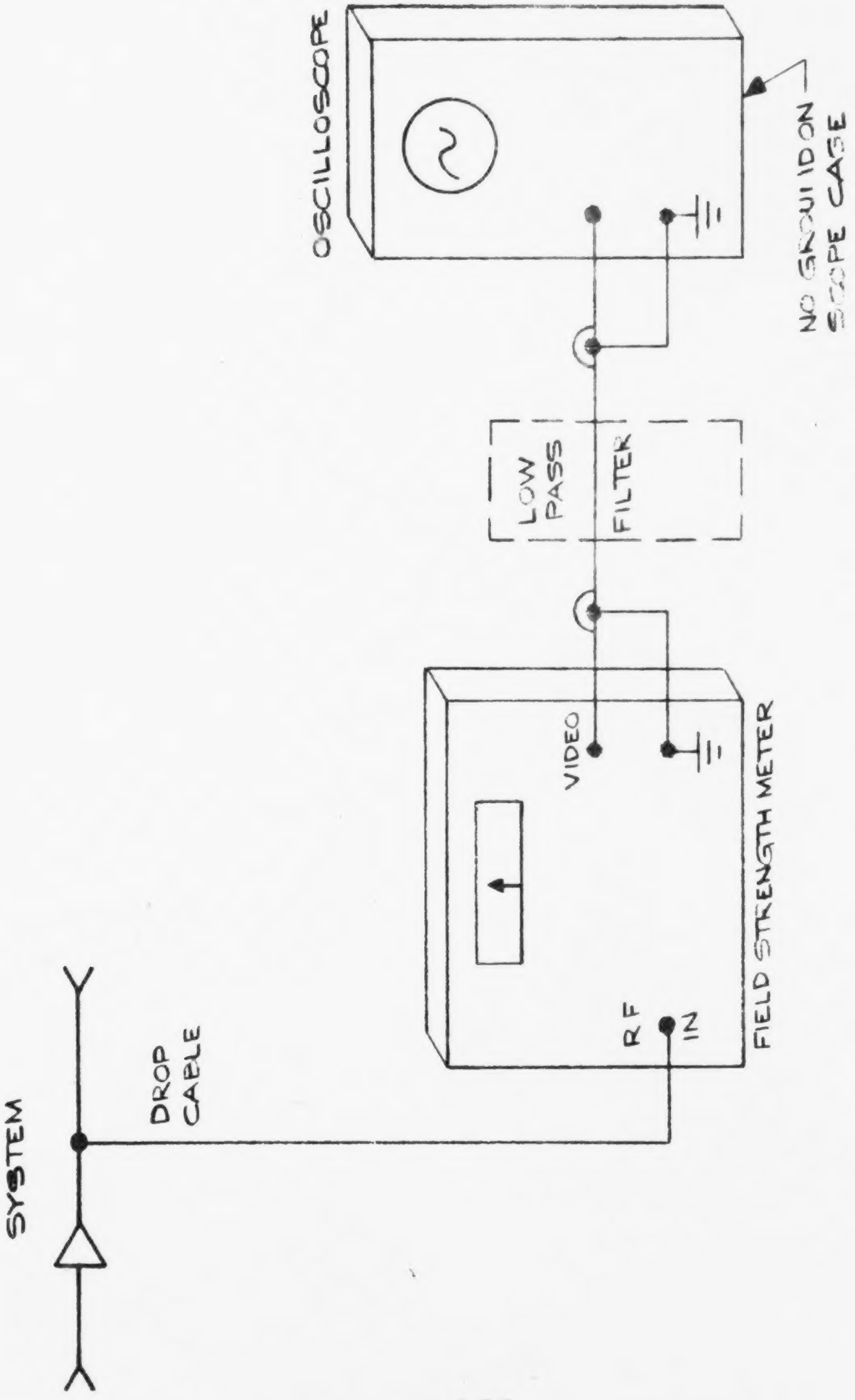
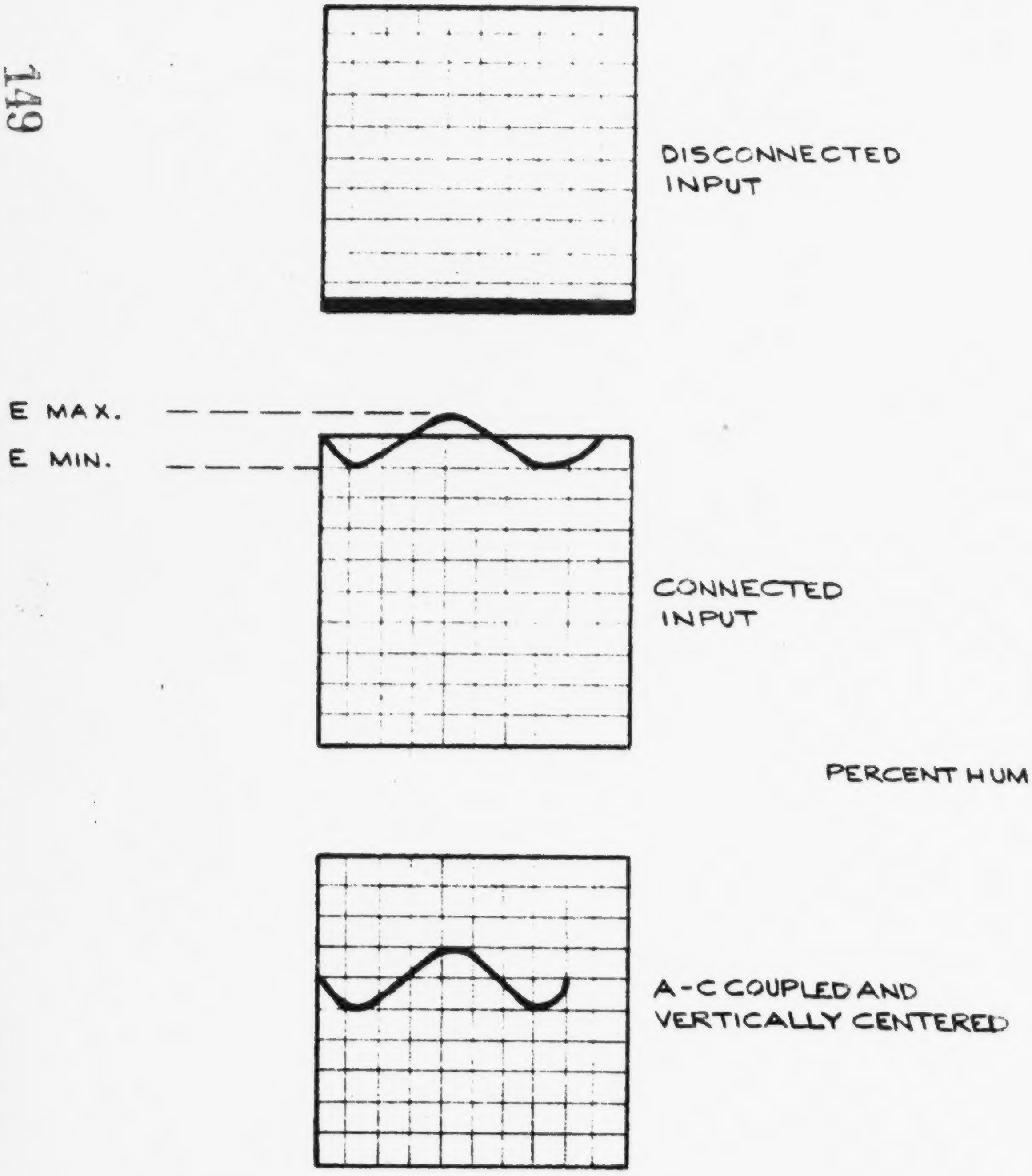

SYSTEM
DROP CABLE
RF IN
FIELD STRENGTH METER
VIDEO
LOW PASS FILTER
OSCILLOSCOPE
NO GROUND ON SCOPE CASE

FIG. 10


DISCONNECTED INPUT
E MAX.
E MIN.
CONNECTED INPUT
A-C COUPLED AND VERTICALLY CENTERED

$$\text{PERCENT HUM MODULATION} = \frac{\text{E MAX.} - \text{E MIN.}}{\text{E MAX.} + \text{E MIN.}} \times 100$$

FIG. 11

6. Set the field strength meter to "Manual Gain" and adjust gain until the meter reads full scale. Now adjust scope gain and centering so that, with the signal source disconnected, or the vertical input grounded, the trace is on the bottom line of the oscilloscope, and with the source reconnected it goes to the tenth line. This adjustment sets the relation between oscilloscope deflection and C-W level so that each division on the screen utilized represents a 10% change in level. Since hum modulation is usually symmetrical (varying both above and below the modulated level) percent modulation follows the rule

$$\text{Percent Mod.} = 100 \times \frac{\text{Emax} - \text{Emin}}{\text{Emax} + \text{Emin}}$$

Referring to Fig. 11

7. For convenient measurement, switch the scope to a a-c coupling and center the trace vertically. If the % modulation is so low that it cannot be measured, increase the scope gain 10 times and divide the final percentage hum modulation reading by 10.

A low pass filter may be utilized between the field strength meter and the oscilloscope if you desire to reduce the amount of system noise present during the measurement.

The low pass filter is usually not required unless you are attempting a measurement of 1% or less. An ordinary power combiner with the AC side connected to the oscilloscope will fill the bill.

CHANNEL FREQUENCY RESPONSE

The channel frequency response is a measurement of system gain at various frequencies within the 6 MHz bandwidth assigned to each standard television channel. The methods of measurement are related in concept to the approach taken in normal bench sweep techniques with a few changes in procedure necessary to insure accurate results.

1. The continuous method.

    a. Standard sweep generator located at head-end, operated at low sweep levels.

b. Produces severe interference on television receivers.

c. Requires traps at AGC carrier frequencies to reduce sweep energy contribution, which alters AGC amplifier levels.

2. The simultaneous method.

a. Simultaneous sweep transmitter located at head-end, operated at high sweep levels.

b. Produces unobjectionable interference on television receivers.

c. Increased equipment cost.

Both approaches are basically the same. A carrier is swept from the lowest system frequency to the highest. The effects of system gain at various frequencies within the system pass-band produce variations in the amplitude of the CW carrier as it travels through high and low gain points in the passband. The sweep receiver unit transforms the RF amplitude variations to DC variations. The DC variations are then displayed on an oscilloscope in the form of a trace. The high and low points of the trace can be frequency identified by mixing a known RF signal with the sweep prior to detection. This will cause a beat on the trace at the point the sweep frequency coincides with the known RF marker signal. The difference in system gain at different frequencies may now be determined by adding a variable attenuator prior to the sweep receiver and adding attenuation until the frequency with the highest amplitude rests at the same point on the oscilloscope as the frequency with the lowest amplitude occupied prior to the level decrease.

Fig.12 is an illustration of the simultaneous sweep system. The sequence is as follows for a 500 kc to 300 MHz sweep.

1. A variable rate generator in the transmitter triggers a ramp generator.

2. The ramp generator begins at "0" volts and increases in a linear fashion to seven volts.

3. The ascending ramp voltage frequency modulates the sweep generator. When the ramp voltage increases the sweep generator output frequency increases.

4. The output of the sweep generator is passed through a "diode gate," and into the trunk system.

5. During the 2 millisecond sweep time the CW carrier has progressed from 500 kc to 300 MHz and the system non-uniformities in gain have acted on all the individua frequencies within the system passband.

6. The sweep receiver detects the sweep signal and displays the resultant information on a CRT.

Fig.13 indicates two time marks. Ignoring any delays in time due to signal propagation or group delay will aid in explaining the trace display.

Time 1 shows the ramp voltage at four volts. When the ramp input to the sweep generator is four volts the sweep generator output is at 160 MHz and the system for this instant in time is amplifying a CW carrier at 160 MHz. The trace on the CRT indicates the amount of gain the system exhibits at 160 MHz.

Time 2 shows the same informations, only this time at 240 MHz. Ramp voltage = 6.2 volts, frequency = 240 MHz. The trace indicates that 160 MHz is 3 dB lower in amplitude than 240 MHz. This may be due to lower amplifier gain at 160 MHz relative to 240 MHz, or excessive loss in a passive or passive devices at 240 MHz.

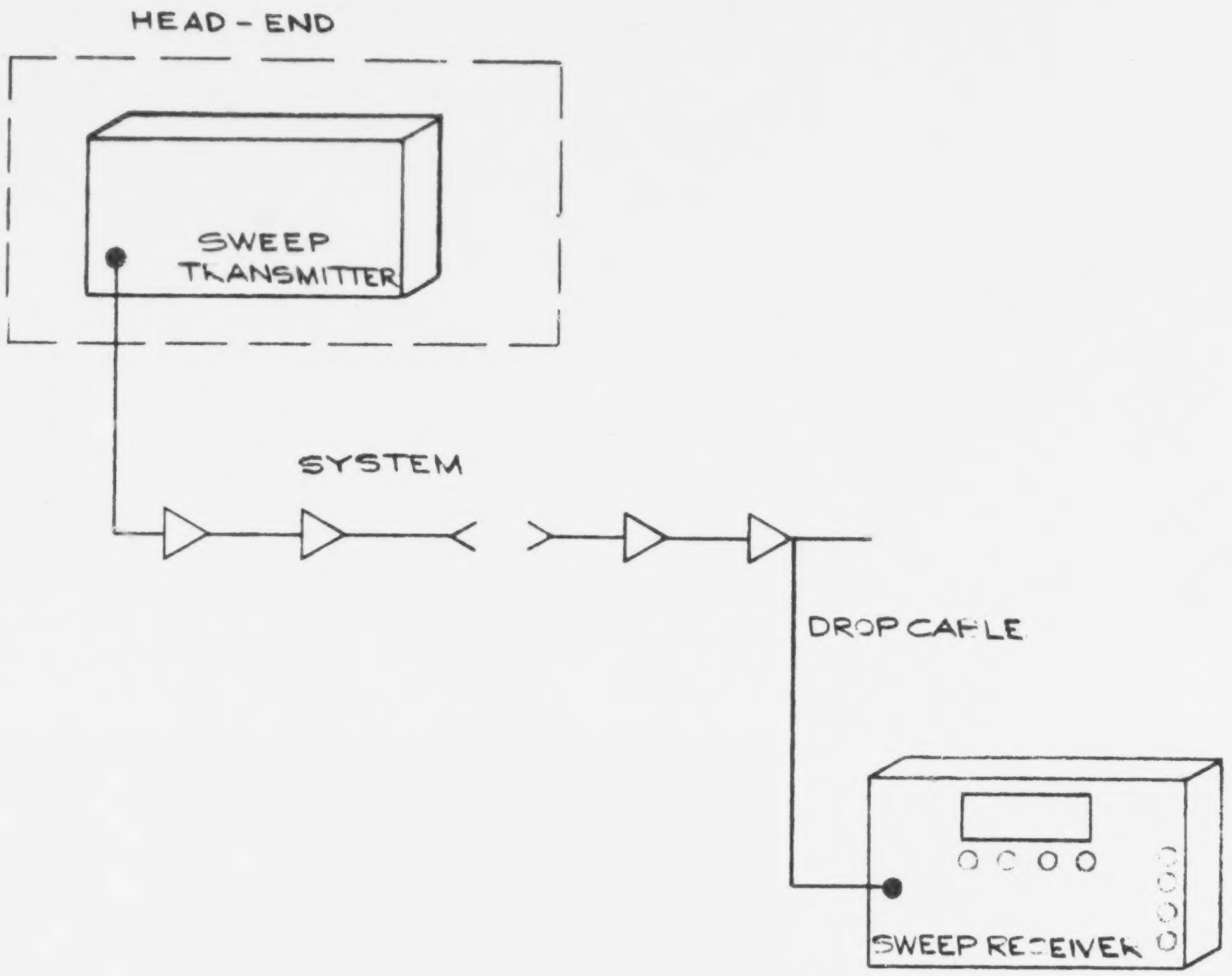
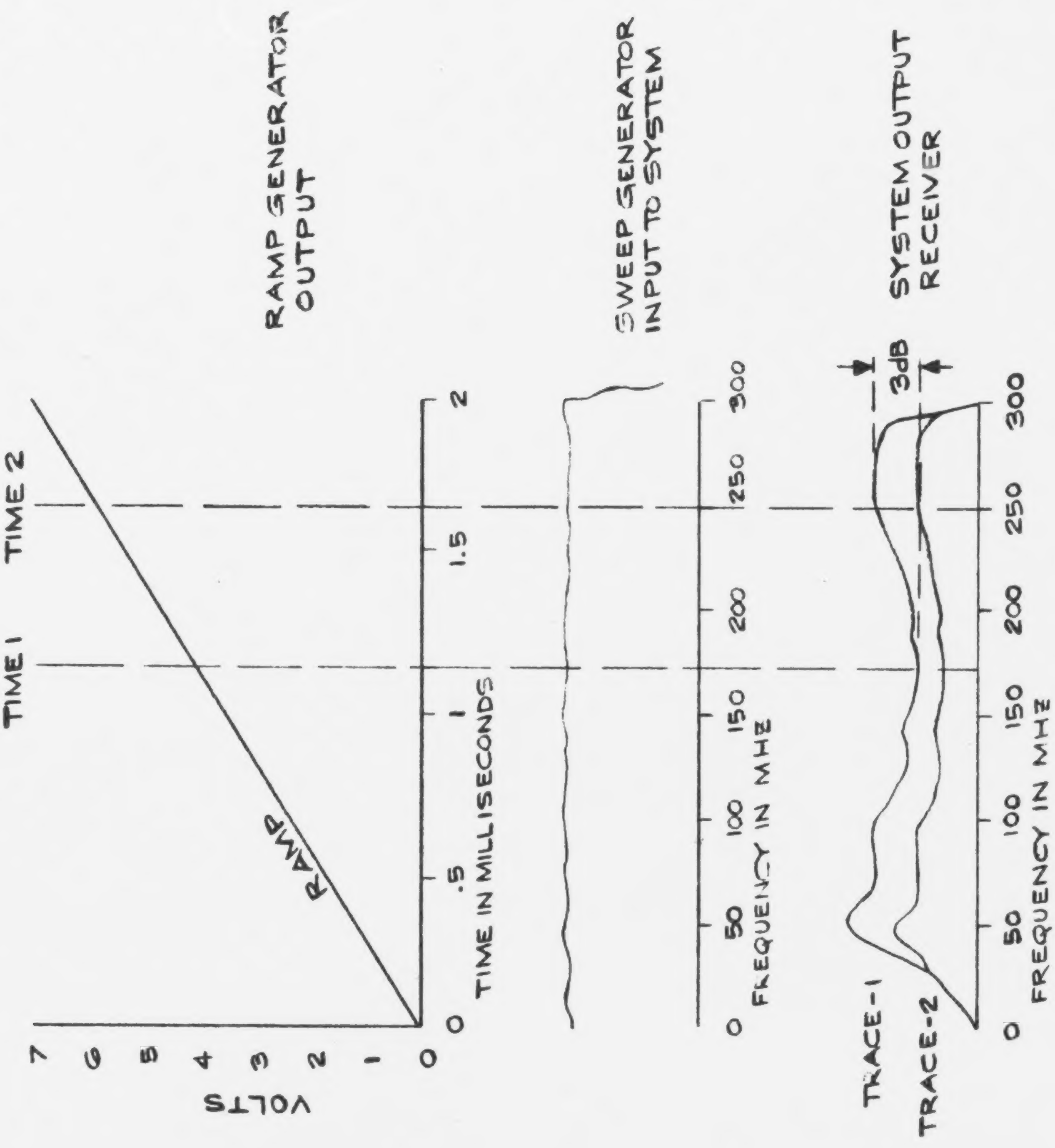

HEAD - END
SWEEP
TRANSMITTER
SYSTEM
DROP CABLE
SWEEP RECEIVER

FIG. 12

FIG.13

SIMULTANEOUS SWEEP SYSTEM


TIME 1
TIME 2
RAMP
VOLTS
0
1
2
3
4
5
6
7
0
.5
1
1.5
2
TIME IN MILLISECONDS
RAMP GENERATOR OUTPUT
SWEEP GENERATOR INPUT TO SYSTEM
0
50
100
150
200
250
300
FREQUENCY IN MHZ
SYSTEM OUTPUT RECEIVER
3dB
TRACE-1
TRACE-2
0
50
100
150
200
250
300
FREQUENCY IN MHZ

THEORETICAL CONVERSION FOR CROSS MODULATION DISTORTION

TEST SIGNAL		SYSTEM CAPABILITY		CROSS-MOD CONVERSION FACTOR
NO. OF CHANNELS	BLOCK TILT*	NO. OF CHANNELS	BLOCK TILT*	
9	3 dB	12	3 dB	-3.8
9	3 dB	21	3 dB	-7.5
9	3 dB	27	3 dB	-10.8
12	3 dB	21	3 dB	-3.7
12	3 dB	27	3 dB	-7.0
21	3 dB	27	3 dB	-3.3
9	5 dB	12	5 dB	-4.4

* The tilted channels are the 5 low band VHF channels and (if applicable) the 9 mid-band TV channels.

KEY FREQUENCY PARAMETER MEASUREMENTS AND INSTRUMENTS

Linley Gumm
Project Engineer
Tektronix, Inc.

Measuring CATV system performance has been spotlighted by new FCC rules requiring periodic system performance tests. But, then, system performance measurements have always been important, and in recent years have been receiving increasing attention. Also receiving increasing attention are spectrum analyzers to meet measurement needs.

Figure 1 shows a synopsis of the FCC's specifications as well as a list of specifications that might be used as engineering standards in a high quality system. Of course, the engineering standards are considerably tighter since the aim of establishing these standards is to achieve nearly flawless performance. All of the standards relating to signal amplitude, spurious signals, cross modulation, signal-to-noise ratio, hum and radiation can be measured easily with a spectrum analyzer. However, some of these standards such as carrier frequency and system flatness cannot be measured by spectrum analyzers alone. In the past few years, great strides have been made in spectrum analyzer performance. Spectrum analyzers such as the TEKTRONIX 7L12 are available with absolute calibration that reads the input level directly without external calibration. They also have accurate logarithmic displays that read directly in dB, as well as highly linear, calibrated frequency sweeps for making frequency difference measurements, plus many more features that make RF measurements easy.

Other, more economical, spectrum analyzers such as the TEKTRONIX 1401A-1 with fewer features are also available. This analyzer also has a logarithmic display, linear in dB, but it cannot make level measurements without first referring to its internal calibrator. This is a slight inconvenience when compared to the 7L12, but it is a relatively easy instrument to use. The striking advantage of the 1401A-1 is that it is a small, light, highly portable battery-operated instrument suitable for field work. But it is restricted somewhat in performance and cannot make some of the more difficult measurements. However, it can make all of the amplitude measurements with ease.

All Standards Relate to Values at Subscribers' Terminals

AMPLITUDE STANDARDS	FCC	DESIRED ENGINEERING STANDARDS
a) Minimum visual sync-tip level	0dBmV	+3dBmV
b) Maximum visual sync-tip level	Below overload	+10dBmV
c) Maximum amplitude difference between visual carriers 6MHz apart	3dB	1dB
d) Maximum amplitude difference between any visual carriers	12dB	7dB
e) Minimum visual/aural ratio	13dB	13dB
f) Maximum visual/aural ratio	17dB	17dB
g) Maximum FM station amplitude		-7dBmV
h) Minimum FM station amplitude		-20dBmV
i) Maximum variation between FM stations on adjacent channels		3dB
j) Long-term variations in amplitude	12dB	
FREQUENCY STANDARDS		
a) Visual frequency accuracy	±25kHz	±25kHz of standard channel frequency
b) Intercarrier frequency	4.5MHz ± 1kHz	4.5MHz ± 1kHz
c) FM frequency accuracy		±2kHz of standard channel frequency
CATV SYSTEM FLATNESS SPECIFICATIONS		
a) Amplitude response within any TV channel	±2dB	±.5dB (-.75MHz + 3.6MHz from visual carrier)
b) Amplitude response for entire spectrum		±2dB
SYSTEM FAULT STANDARDS		
a) Hum or low frequency variations	5% peak to peak	1%
b) Visual carrier to noise ratio (4MHz BW)	36dB min.	40dB
c) Visual carrier to coherent spurious signal ratio (i.e., intermodulation)	46dB min.	-45 to -60dB (depending on position with respect to visual carrier)
d) Cross modulation ratio		-51dB (-57dB trunk)
e) Reflections within system (shadows)		-40dB
ISOLATION		
a) Subscriber to subscriber isolation	18dB	30dB
RADIATION		
a) Up to 54MHz	15μV/M @ 100'	
b) 54 to 216MHz	20μV/M @ 10'	
c) Above 216MHz	15μV/M @ 100'	
VIDEO CHARACTERISTICS (BASE BAND SYSTEMS)		
a) Differential gain		.5dB
b) Differential phase		±1 degree
c) Envelope delay variations		Per FCC Standards

Fig. 1. CATV system specifications.

AMPLITUDE MEASUREMENTS

Figure 2 shows a spectrum analyzer display of a typical TV signal. The visual carrier is the large signal to the left, and the aural carrier is the large signal to the right. The smaller signal between the visual and aural carrier is the chroma subcarrier, carrying the color information in the picture. Measurement of the visual carrier frequency is made with a TEKTRONIX Type 7D14 Digital Counter. The character readout of this frequency is at the top left on the CRT. The rest of the readout presents most of the pertinent scale factor information needed to interpret the photo. The upper center format indicates the vertical scale factor of the display as 10 dB per division in this case. The upper right indicates the input signal level to produce full scale deflection, or -10 dBm. The 6 dB minimum-loss pad is used to convert the input impedance to 75 Ω. To convert the reading to dBmV, add 55 dB to the reading in dBm. In this case, the output level is +45 dBmV. The format at the lower left indicates the bandwidth that the analyzer IF uses to separate the various components (resolution bandwidth) is 30 kHz. At the lower right, the readout indicates the horizontal scale is 1 MHz per division.

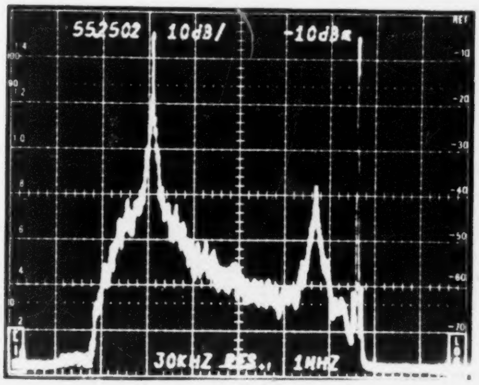


Fig. 2. Typical TV signal. A 7D14 was used to measure the visual carrier frequency.

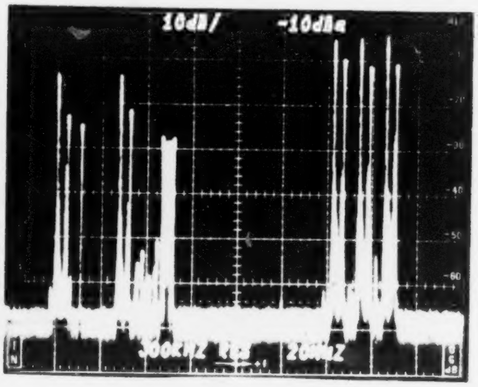


Fig. 3. CATV head end output.

Figure 3 shows the head end output of a CATV system. The system is located in Portland, Oregon, where, before the new FCC rules, it could not import any foreign signals. Therefore, the system is lightly loaded, carrying only the six local TV signals (2, 3, 6, 8, 10, 12), as well as nine FM stations. At the time this photo was taken, Channel 3 was not on the air.

The photo shows the general condition of the head end: the readout shows that the vertical scale factor is 10 dB per division and the reference level is -10 dBm (+45 dBmV). Channel 2 is the first signal on the left, with the visual and aural carriers in the same relative positions as in Figure 2. The visual level of Channel 2 is +31 dBmV and the aural level is +22 dBmV for a visual/aural ratio of 9 dB.

The large carrier just to the right of Channel 2 is the aural output of the Channel 3 strip amplifier when Channel 3 is off the air. The Channel 3 visual output under these conditions is just to the right of the Channel 2 aural carrier at a level of -70 dBm (-15 dBmV). Channel 6, the next TV station, is correctly operating at the same output level as Channel 2, but with a 3 dB less visual/aural ratio. The low-level signals above Channel 6 are the unprocessed FM carriers as broadcast, leaking through onto the cable. The block of carriers just above the FM carriers are the processed FM signals at an amplitude of -38 dBm (+17 dBmV). The high-band signals (Channel 8, 10, 12) are all within 2 dB of each other, and 9 dB greater in amplitude than the low-band signals; this system employs block tilt. After the various low-level signals between the carriers are identified, a photo such as this can serve as a system record that even includes a tabulation of some of the spurious signals.

Moving the frequency span to 10 MHz per division and slightly retuning the center frequency, we arrive at Figure 4. Here a more detailed view of the low band and the FM band is obtained. Note the two spurious signals below Channel 2. The close-in one, being 46 dB down from the Channel 2 carrier, will cause no problem. A detailed look at the high band is presented in Figure 5.

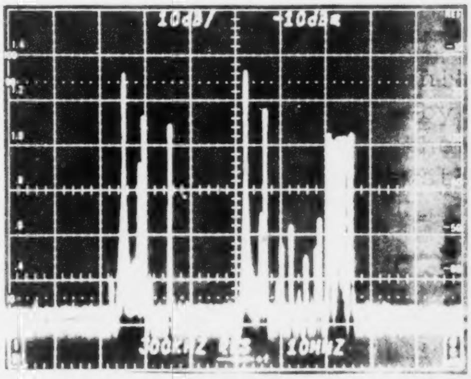


Fig. 4. Low band and FM band output. Channel 2's level is +31 dBmV.

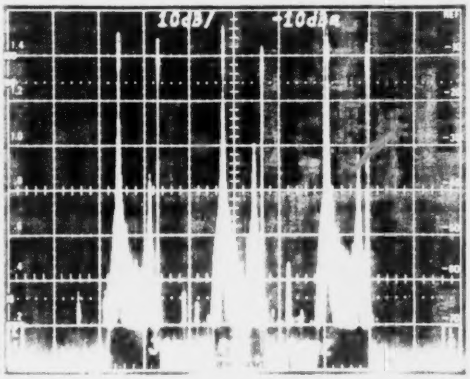


Fig. 5. High band output. Channel 2's output level is +40 dBmV.

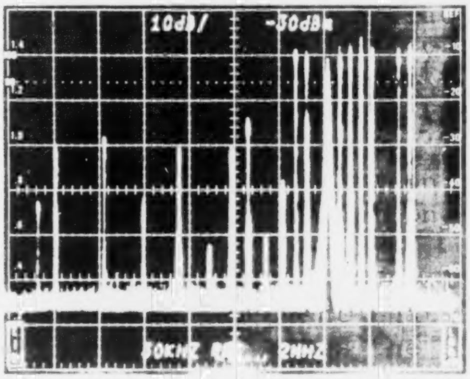


Fig. 6. FM band output. The processed FM output level is about +16 dBmV.

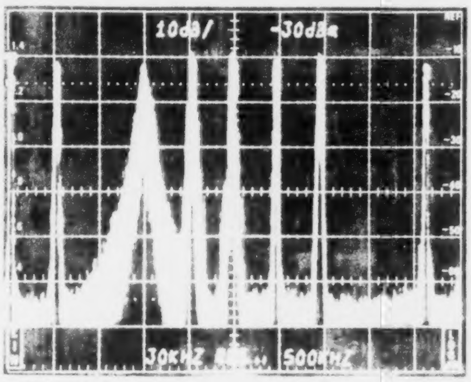


Fig. 7. Output of FM processors. One unit is misadjusted.

Figure 6 shows the FM band. The processed signals are at the high end of the band and are about 20 dB higher than the unprocessed signals at the low end. As shown in Figure 7, the processed signals are at 0.5 MHz spacing with the exception of two gaps left open since these are unassigned FM broadcast allocation frequencies. Note the signal that is much wider than the rest. An oscillator was misadjusted and the converter was nonoperational. This was found as these pictures were being taken, and a quick adjustment by the technician put the converter back in business.

To make highly accurate amplitude measurements, the 7L12 has been provided with a 2 dB per division mode. Figure 8 is a picture of the high-band carriers' amplitudes. With this 2 dB per division vertical scale factor, we can observe that Channel 8 is operating at -13.4 dBm (+41.6 dBmV) and Channels 10 and 12 are within 1 dB of the same level. The more sensitive 2 dB per division scale factor affords easy and accurate power measurements. Periodic checks of the spectrum analyzer's accuracy are easily done with an internal calibrator.

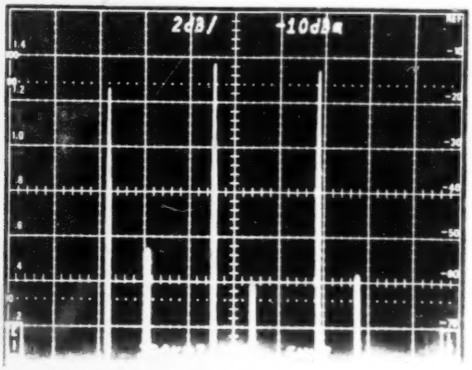


Fig. 8. High band output at 2 dB per division Channel 8's level is +41.6 dBmV.

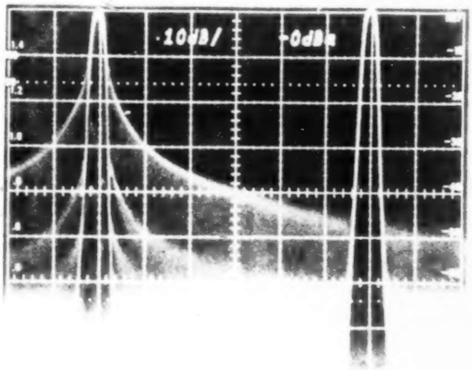


Fig. 9. Cross modulation measurement. Lower frequency carrier modulated with a 15.75 kHz squarewave. Higher frequency carrier is CW.

SYSTEM FAULT MEASUREMENTS

Cross modulation. As in most things, the economy models of spectrum analyzers cannot do some of the things that more elaborate ones can do. This is the case in cross-modulation measurements. The 7L12 can make this measurement with ease, but the 1401A-1 lacks high resolution circuitry.

Cross modulation is generally measured[1] by applying thirteen visual carriers of the VHF spectrum at the correct operating level to the input of the amplifier to be tested. Twelve of the thirteen carriers are simultaneously modulated with a 15.75 kHz squarewave, while the thirteenth carrier is left unmodulated.

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[1] NCTA Spec 002-0267, *CATV Amplifier distortion characteristics.*

This thirteenth carrier is then carefully tested at the amplifier's output to see if it has become modulated by passing through the amplifier simultaneously with the twelve modulated carriers.

Figure 9 shows one of the modulated carriers next to the unmodulated carrier. The analyzer is set for a 300-kHz resolution bandwidth, which gives a full peak reading of the carrier amplitude. From the photo, we ascertain that the two carriers are of equal amplitude. The second step is tune to the modulated carrier and measure the amplitude of the 15.75-kHz sideband. This amplitude is the calibration level for the actual measurement. Figure 10 shows this measurement. The carrier has fallen 6 dB in amplitude because we are now measuring the average amplitude of the carrier instead of seeing its peak amplitude. The first sideband is down 12 dB. The third step is to tune to the unmodulated carrier and again measure the amplitude of the first sideband. Figure 11 shows this measurement. The 15.75-kHz sideband is down 65 dB. The cross-modulation ratio is -65 dB + 12 dB = -53 dB.

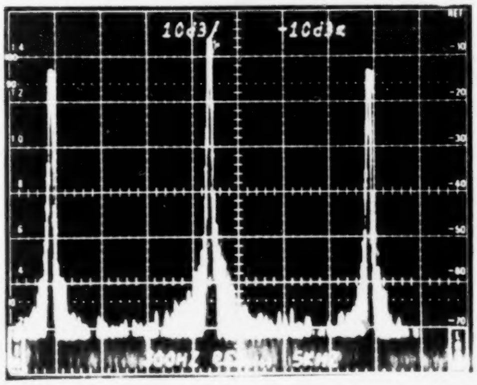

Fig. 10. Cross modulation measurement. This is the modulated carrier with its first 15.75 kHz sidebands.

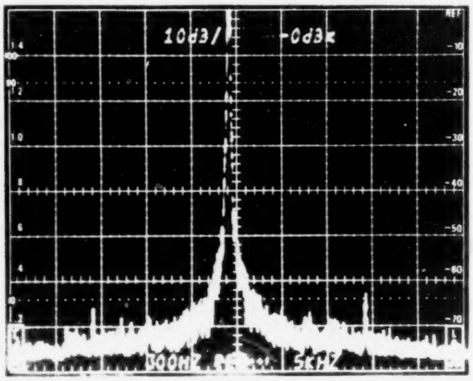

Fig. 11. Cross modulation measurement. This is the CW carrier with its low level 15.75 kHz sidebands. The cross modulation level is -53 dB. (Sideband level Fig. 10 - Sideband level Fig. 11)

Note that with a 15.75 kHz squarewave of reasonable symmetry, the calibration of step two will be within a dB or so of 12 dB. In Figure 11, the first sideband is about 5 dB above the noise floor of the spectrum analyzer. Therefore, the 7L12 is capable of measuring cross modulation down to about -58 dB.

Intermodulation. Intermodulation occurs when two signals applied to an amplifier produce more than two signals at the amplifier output because of nonlinearity. The 1401A-1 can measure intermodulation 60 dB down. The 7L12 can measure intermodulation to a level of 70 dB down. Figure 12 shows a typical measurement. Channel 8 is on the right and Channel 10 on the left. Between them are two low level signals that are the result of the third order curvature of the amplifier. The visual and aural carriers of Channel 8, which are 4.5 MHz apart, combine to form an intermodulation spurious·product 4.5 MHz above and below aural and visual carriers, respectively[2]. The small signal just below Channel 10's visual carrier is one of the intermodulation products produced by Channel 8. Similarly, the small signal just above Channel 8's aural carrier is one of the intermodulation products produced by Channel 10. In this case they are about 57 dB below the visual carriers.

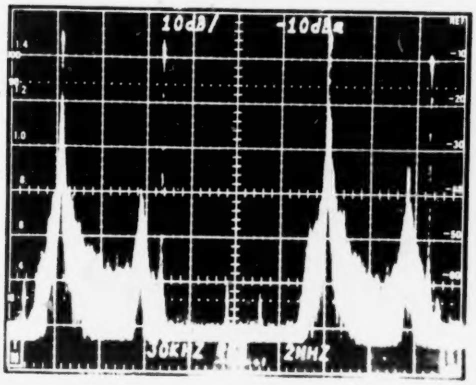

Fig. 12. Intermodulation measurement. Intermodulation is 57 dB down.

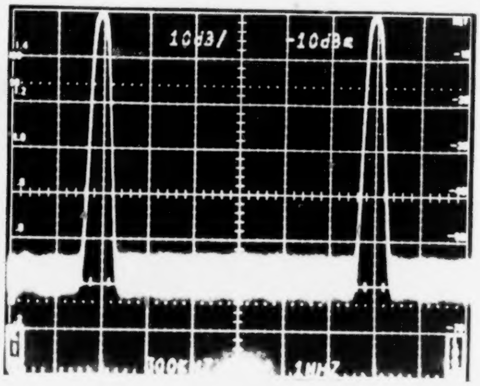

Fig. 13. Noise measurement. The signal to noise ratio is 45 dB.

Noise. A spectrum analyzer can easily measure a signal-to-noise ratio. In the case of a CATV system, the measurement can be made directly without any special techniques if the S/N ratio is 50 dB or less. Figure 13 shows this measurement. The system is operating in its normal mode, except substitution carriers have replaced all of the signals. The noise is at a uniform level between the two carriers at -53 dB down from full screen. The 7L12 spectrum analyzer's bandwidth is 300 kHz so this number must be modified to allow at the 4 MHz S/N ratio used in CATV measurements. The amplitude difference between 4 MHz and 300 kHz noise bandwidths is 11 dB[3]. However, logarithmetic displays read about 2 dB low in noise measurements. Therefore, the 4 MHz S/N measurement of this system is 58 - 11 - 2 = 45 dB.

Co-Channel Interference. Only the more elaborate analyzers such as the 7L12 can make this measurement. Figure 14 shows the carrier and the first two 15.75-kHz sidebands of a TV signal. 10 kHz above the carrier is another signal that is another TV carrier assigned to the same channel but offset by 10 kHz in frequency. Note that the 7L12 is capable of making this measurement down to about the -60 dB level.

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[2] Kenneth L. Simons. "The Decibel Relationships Between Amplifier Distortion Products," *Proc IEEE*, Vol 58 #7 July 1970.

[3] NCTA Spec 002-0267, *CATV Amplifier distortion characteristics.*

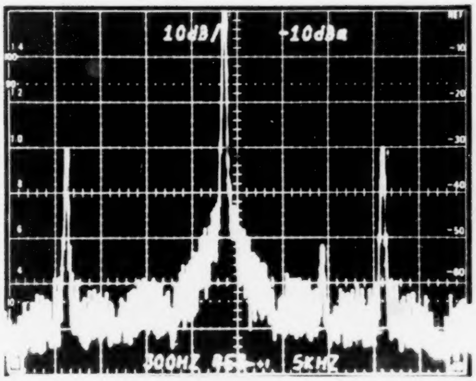

Fig. 14. Co-channel interference. The co-channel signal is 51 dB down.

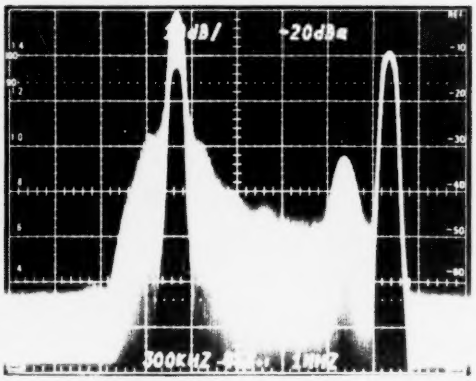

Fig. 15. Typical TV signal.

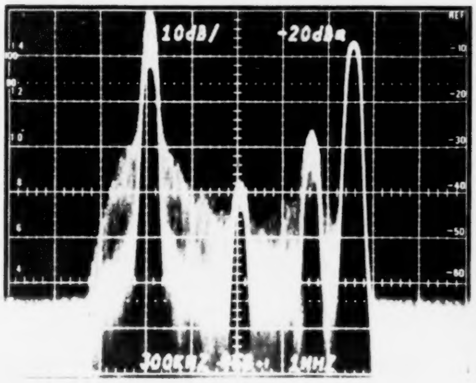

Fig. 16. TV signal with 40 dB down interfering signal.

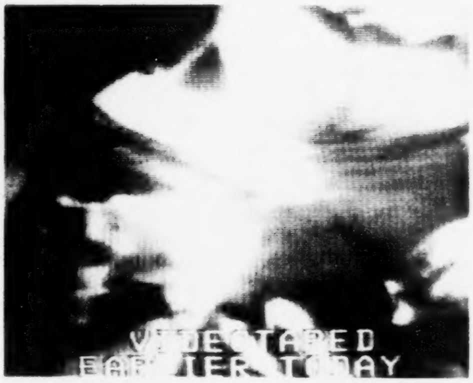

Fig. 17. TV picture with 40 dB down interfering signal.

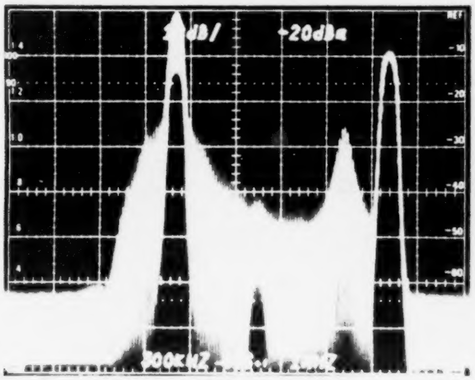

Fig. 18. TV signal with 50 dB down interfering signal.

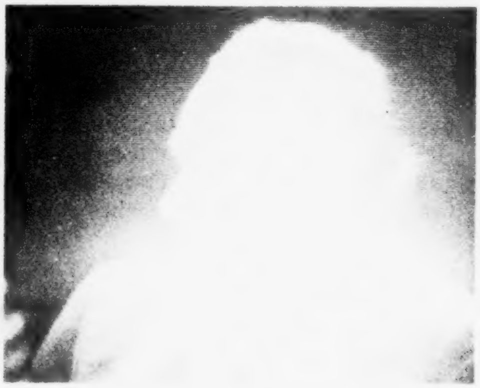

Fig. 19. TV picture with 50 dB down interfering signal.

Interfering Signals. We've already discussed stray and interfering signals away from the TV signals. But what about interfering signals within a TV channel? To explore this point, some tests were run in the lab deliberately adding a CW signal to a TV signal and observing the result. Figure 15 is a normal TV signal. Figure 16 shows the same signal with a 40 dB down interfering signal 2 MHz above the visual carrier. Figure 17 shows the resultant herringbone on the TV picture. Figure 18 shows the same interfering signal, but it is now 50 dB down. The resulting herringbone shown in Figure 19 is just perceptible, lowering the interfering signal's amplitude by another 10 dB to -60 dB below sync tip results in a still visible signal in the spectrum analyzer display in Figure 20, but results in no visible picture degradation. When there is doubt about whether or not some feature within the spectrum analyzer display at a TV signal is an interfering signal, the problem can be resolved by looking at the display over a period of time as the picture content changes. Any fixed low-level feature, with the exception of the chroma signal, is probably an interfering signal.

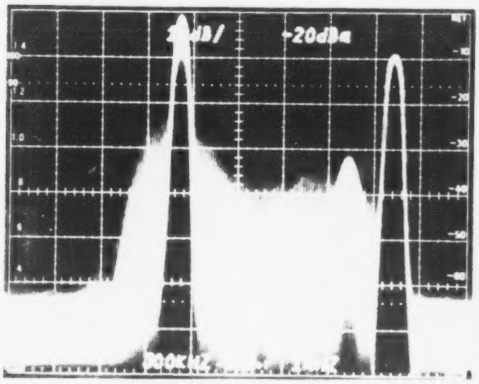

Fig. 20. TV signal with 60 dB down interfering signal.

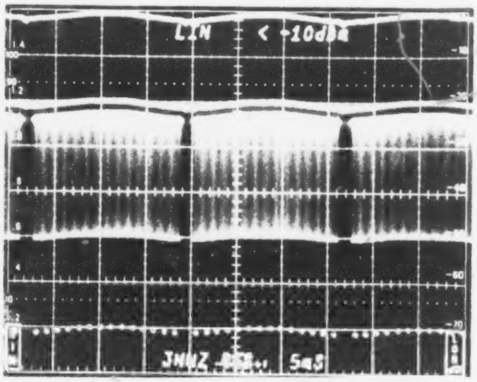

Fig. 21. Hum measurement. Hum is 2.5% P-P of sync tip amplitude.

Hum. Hum can be measured by using the spectrum analyzer as a wideband receiver and viewing the resulting video with respect to time. Figure 21 shows the 7L12 being used as a 3-MHz bandwidth receiver to look at a TV transmitter. When the frequency span control of the 7L12 is set to zero, the CRT readout display reads the time per division of the sweep instead of frequency per division. The linear scale is used for maximum sensitivity. The line across the top of the screen is the sync tip level. The sync tip level is varying .2 divisions with a full scale deflection. Therefore, the hum is .2 : 8 = 2.5%.

Radiation. Radiation is measured by using a calibrated antenna and measuring the amplitude of the signals by it. Reference must be made to a correction chart provided by the antenna manufacturer before the actual field strength may be determined.

Testing for signals leaking from CATV systems may be a frustrating experience. It will be difficult to separate the signal picked up directly from the signal that is leaking from the cable. Only when signals on the cable are at a different frequency will it be possible to get an unambiguous reading. Adding CW signals at some unused frequencies to the CATV system's normal load and at the same level as the visual signals may aid in measuring radiation levels with less confusion.

Conclusion. The author has attempted to show how, with the aid of a spectrum analyzer, a great many of the difficult, time consuming CATV measurements can be made conveniently. A spectrum analyzer is not the only measuring instrument a CATV operator needs. But, it is a basic instrument that makes many measurements by itself, and enhances the measurement capability of many other pieces of test equipment.

SUMMARY OF
FCC TECHNICAL STANDARDS FOR CATV*

Following is an illustrated summary of the principal technical standards established by the FCC. All verification measurements shown in the illustrations were taken *in the field* with a TEKTRONIX 1401A-1 Spectrum Analyzer.

1. Frequency of the visual carrier: 1.25 MHz ± 25 kHz above channel boundary.
    a. At output of converter: 1.25 MHz ± 250 kHz
2. Frequency of aural subcarrier: 4.5 MHz ± 1 kHz above visual carrier.

    Verification of these standards involves high accuracy frequency measurements. These can be made with a TEKTRONIX 7D14 Counter in any TEKTRONIX 7000 Series oscilloscope mainframe with readout.

3. Minimum visual signal level: 1 mV across 75 Ω (see Figure 1).

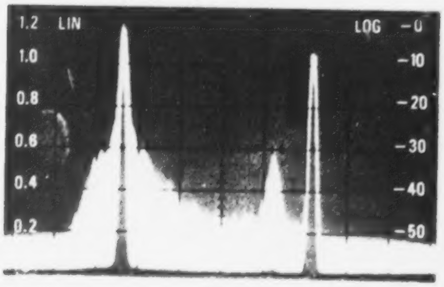

Fig. 1. Visual signal level shown is +10dBmV across 75 Ω; 1401A-1 Spectrum Analyzer has absolute amplitude calibration and 10 dB/div log display.

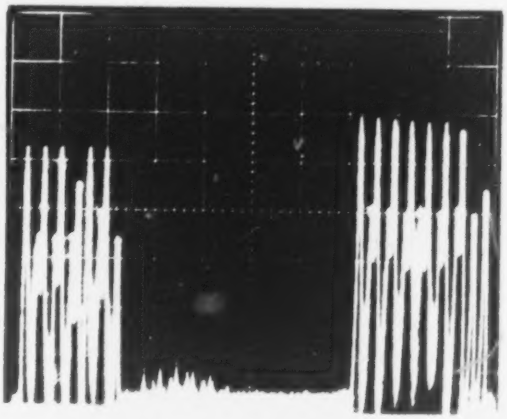

Fig. 2 Photo shows a fully loaded CATV system with high and low band pilot carriers. Vertical log mode is 10 dB/div. (2 dB/div is available in the 7L12 and 2.5 dB/div in the 1401A-1.) The frequency span per division is in an uncalibrated position in this photo to allow closer signal spacing for ease in viewing channel to-channel variations.

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*Extracted from *THAW, New Rules to End the Cable TV Freeze*; National Cable Television Association, Inc.; Washington, D.C.

4. Permissible signal level variation: 12 dB total (see Figure 2).
    a. Maximum adjacent channel variation: 3 dB
    b. Maximum of all channels: 12 dB

5. Maximum signal level: Below threshold of degradation.

   Maximum signal levels are required to be held to values which will not overload a subscriber's receiver.

6. Maximum hum and low-frequency disturbance levels: 5%.

   The peak-to-peak variation in visual signal level, caused by hum, can be measured with a spectrum analyzer in the non-sweeping (zero frequency span) mode. In this mode the analyzer functions as a superheterodyne receiver, followed by a demodulator. Hum modulation can be seen in Figure 21 of previous article.

7. Within channel frequency response: ±2 dB.

   Channel frequency response can be measured with a signal generator, covering the desired range, and the spectrum analyzer. A plot of the signal generator amplitude versus frequency is first made with the spectrum analyzer; then the system response is plotted and the appropriate correction added to the spectrum analyzer displayed amplitude. A sweep generator may be used in lieu of a manually tuned generator.

8. Aural signal level: 13 to 17 dB below visual signal level.

   Aural to visual signal ratios for all channels can be measured easily in one picture (see Figure 2).

9. Signal-to-noise level for all signals picked up or delivered within its Grade B contour: 36 dB (see Figure 3).

10. Signal-to-intermodulation and non-offset carrier interference: 46 dB (see Figure 4).

11. Subscriber terminal isolation: This measurement can be made with a calibrated spectrum analyzer such as the 7L12 or 1401A-1 and a signal generator covering the frequency range of interest. The signal generator output is first measured at the desired reference level (example: 0 dBmV) with the spectrum analyzer. The signal generator is then fed into the line at subscriber (A) and monitored with the spectrum analyzer at subscriber (B). The dB difference between the reference signal and the observed signal can be measured directly. Furthermore, interference to any channel can be observed at a glance.

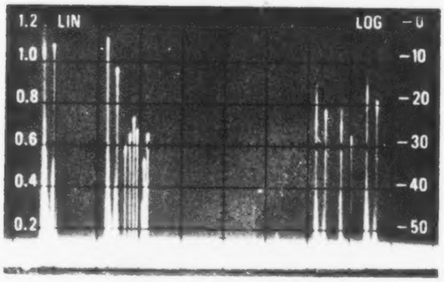


Fig. 3. The photo shows signal-to-noise measurement of low band, FM and high band. Here the vertical log mode is 10 dB/div and the spectrum analyzer resolution bandwidth has been chosen to give a 55 dB dynamic display range. The spectrum analyzer noise floor is measured with the input terminated in 75 Ω. System noise is referred to this level. The 60 dB and 70 dB dynamic ranges are featured on the 1401A-1 and 7L12, respectively.

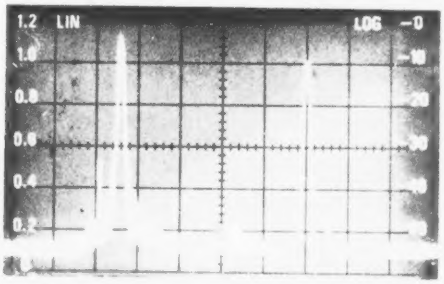


Fig. 4. Photo of 1401A-1 CRT shows spurious response on low side of visual carrier 30 dB below visual carrier amplitude. Spurious response on the high side of the aural carrier is down 46 dB below the visual carrier amplitude. Intermodulation measurements to 60 dB can be made with the 1401A-1 and to 70 dB with the 7L12.

The FCC has not imposed any restriction on frequency usage. Unauthorized radiation at any frequency from a cable system is, however, the responsibility of the cable operator. The new radiation limits are:

Frequencies (MHz)	Radiation Limit Microvolts/meter	Distance from Cable (feet)
Up to 54	15	100
54 to 216	20	10
Over 216	15	100

Radiation in μV/meter can be made easily with the 1401A-1. Figures 5 and 6 show the unit in use with a calibrated antenna. The antenna in the photo is Singer's MD-105-T1, covering 20 MHz to 200 MHz. Figure 7 is a convenient nomograph to obtain μV/meter from the spectrum analyzer reading in dBmV into 75 Ω (1401A-1) or dBm into 50 Ω (7L12).

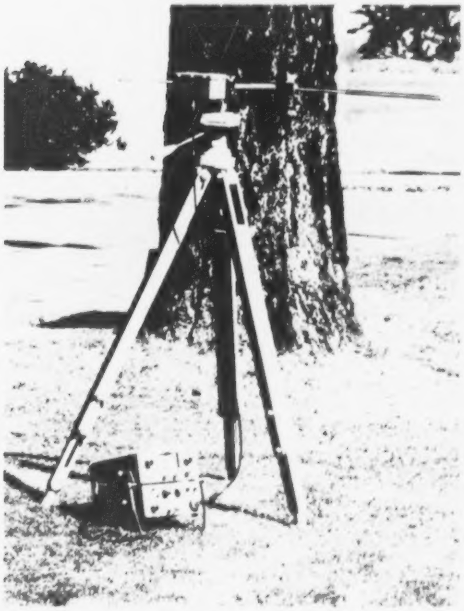


Fig. 5.

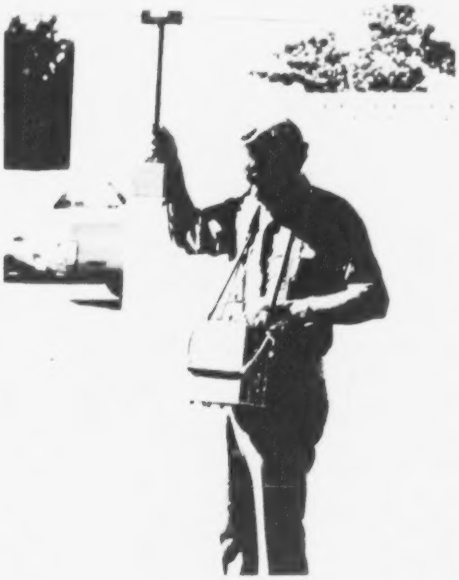
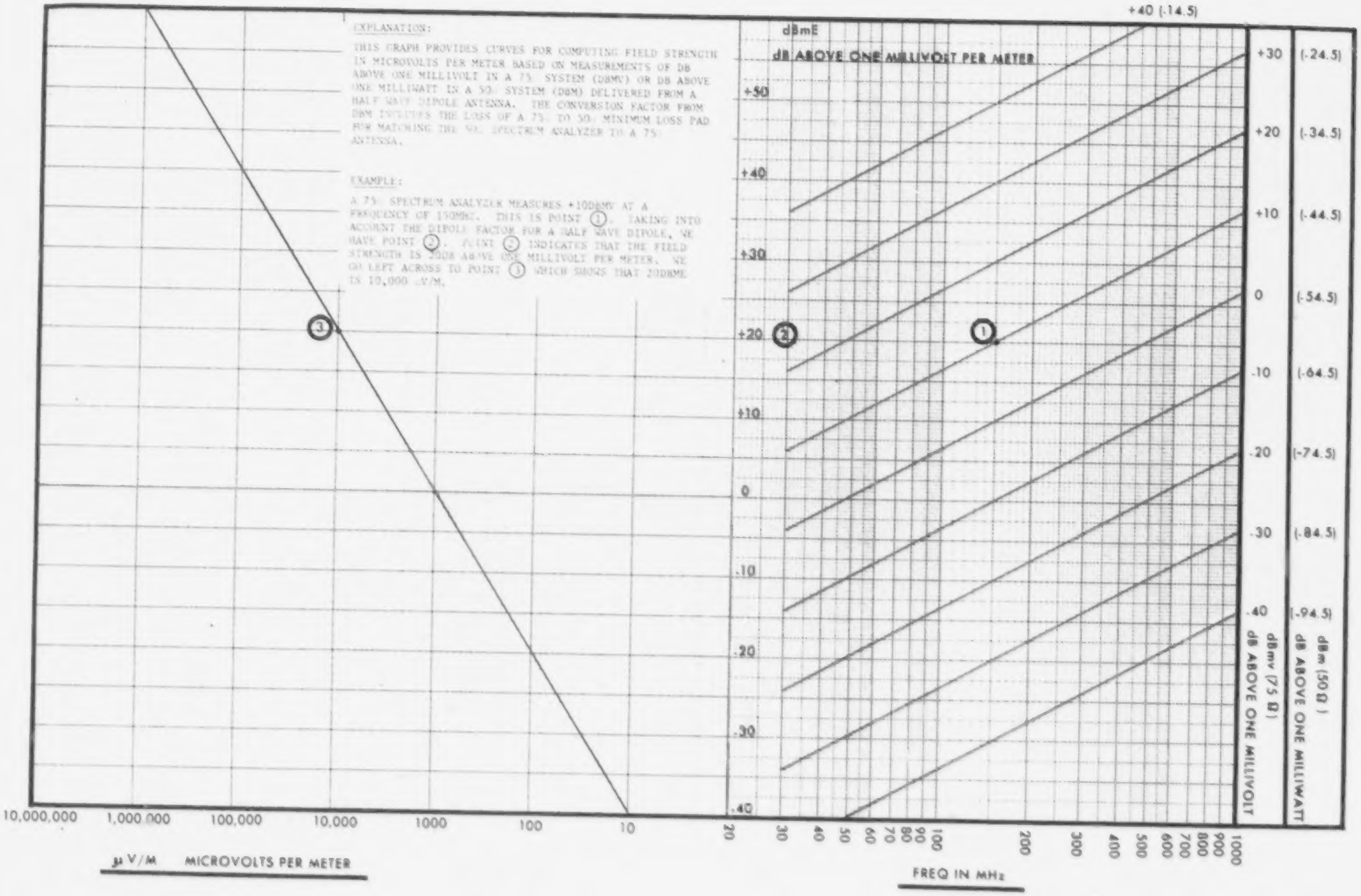


Fig. 6.



EXPLANATION:

THIS GRAPH PROVIDES CURVES FOR COMPUTING FIELD STRENGTH IN MICROVOLTS PER METER BASED ON MEASUREMENTS OF DB ABOVE ONE MILLIVOLT IN A 75Ω SYSTEM (DBMV) OR DB ABOVE ONE MILLIWATT IN A 50Ω SYSTEM (DBM) DELIVERED FROM A HALF WAVE DIPOLE ANTENNA. THE CONVERSION FACTOR FROM DBM INCLUDES THE LOSS OF A 75Ω TO 50Ω MINIMUM LOSS PAD FOR MATCHING THE 50Ω SPECTRUM ANALYZER TO A 75Ω ANTENNA.

EXAMPLE:

A 75Ω SPECTRUM ANALYZER MEASURES +10DBMV AT A FREQUENCY OF 150MHZ. THIS IS POINT ①. TAKING INTO ACCOUNT THE DIPOLE FACTOR FOR A HALF WAVE DIPOLE, WE HAVE POINT ②. POINT ② INDICATES THAT THE FIELD STRENGTH IS 20DB ABOVE ONE MILLIVOLT PER METER. WE GO LEFT ACROSS TO POINT ③ WHICH SHOWS THAT 20DBME IS 10,000 μV/M.

dBmE
dB ABOVE ONE MILLIVOLT PER METER
+50
+40
+30
+20
+10
0
-10
-20
-30
-40
+40 (-14.5)
+30 (-24.5)
+20 (-34.5)
+10 (-44.5)
0 (-54.5)
-10 (-64.5)
-20 (-74.5)
-30 (-84.5)
-40 (-94.5)
dBmv (75 Ω)
dB ABOVE ONE MILLIVOLT
dBm (50 Ω)
dB ABOVE ONE MILLIWATT
①
②
③
10,000,000
1,000,000
100,000
10,000
1000
100
10
μV/M MICROVOLTS PER METER
20
30
40
50
60
70
80
90
100
200
300
400
500
600
700
800
900
1000
FREQ IN MHz

Fig. 7.

WHAT IS A SPECTRUM ANALYZER?

A spectrum analyzer is a device which will decompose a complex electronic signal into its various frequency components. A composite signal as in Figure 1, which is the sum of two sinewaves of frequency F_1 and F_2, will be seen on a normal oscilloscope as just that -- a voltage-time waveform. The scope presents the complex signal as a function of time.

The spectrum analyzer, on the other hand, does not represent signals as a function of time. Over the interval of the observation or measurement, we must assume that the signal has not changed in amplitude or frequency. These variables are our primary concern: What are the frequencies of our signal? What are the amplitudes of the various frequency components? What are these components telling us about the performance of our device?

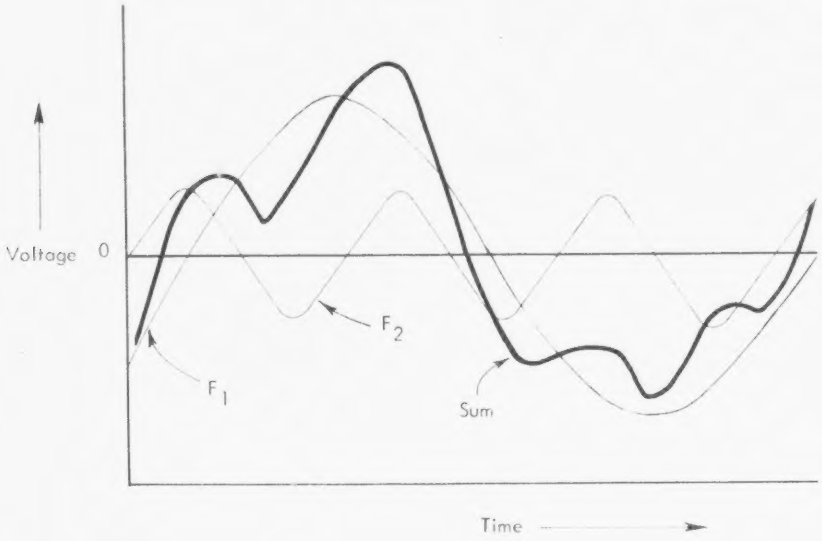


Fig. 1. Composite signal.

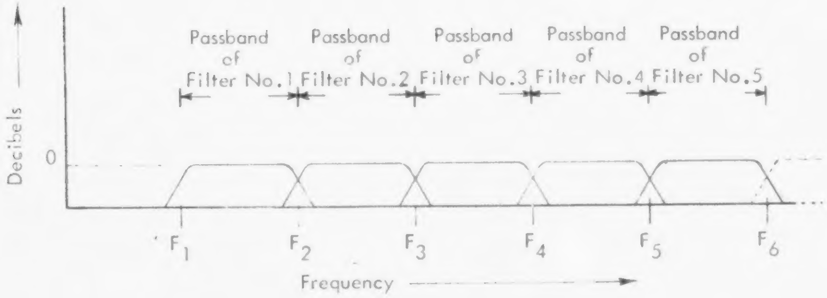

Decibels
0
Passband of Filter No.1
Passband of Filter No.2
Passband of Filter No.3
Passband of Filter No.4
Passband of Filter No.5
F1
F2
F3
F4
F5
F6
Frequency

Fig. 2. Filter passband characteristics.

A very simple spectrum analyzer would be a set of filters. Each filter would have a passband which covers a portion of the frequency spectrum of interest. The filters would successively increase in frequency while their passbands are made to overlap slightly, in order that no portion of the broad range of frequencies over which we intend to study is left gapping. (See Figure 2.) Inputs are connected together so that the complex signal will be common to all filters as shown in Figure 3.

The outputs are connected to a commutator device, a system which will look at the output of each filter sequentially. This commutator device could be as simple as a multiple pole switch or a diode matrix or a Time Division Multiplexer. The commutator, then, is sampling the output of each filter, in turn, and in that time only will the output show a signal which is passing through that particular filter.

This system is known as Filter Spectrum Analyzer. The difficulty with this system is that it takes a great many filters to cover a large frequency range.

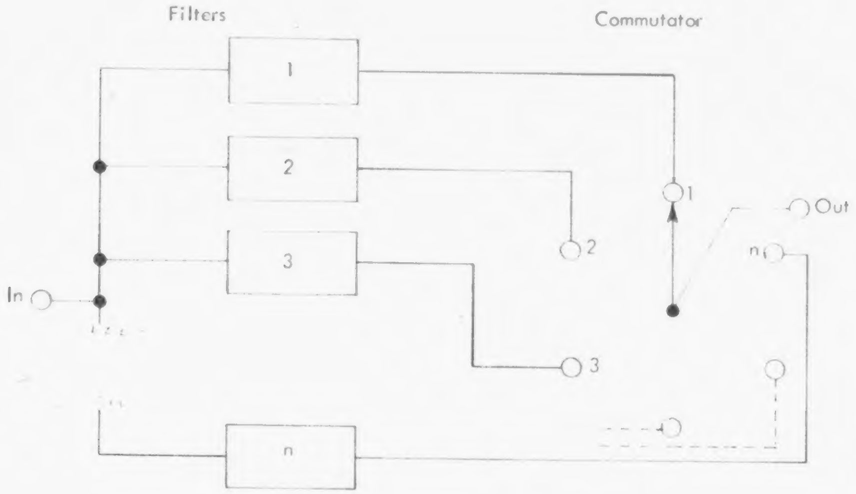
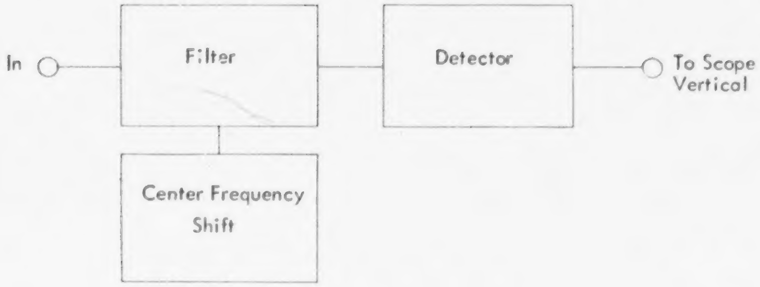


Fig. 3. Simple spectrum analyzer.



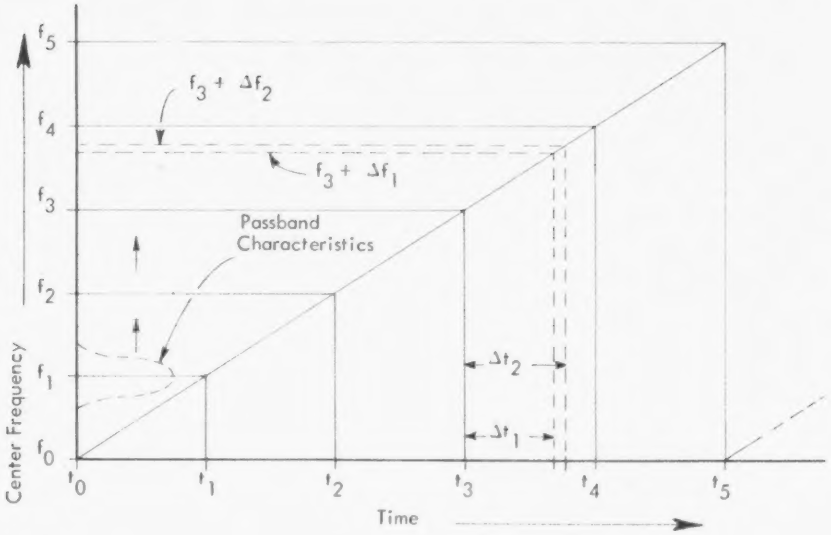


Fig. 4. Swept filter and characteristics.

We can get away from these filters by letting a single one do the switching. This system would have a single filter whose center frequency is adjustable over the frequencies of interest as in Figure 4. Here at t_1, the filter center frequency is located at F_1 and has a passband characteristic shown by the dashed lines. At t_2, the passband has moved to center itself at F_2 (dotted lines). This shifting continues at a constant rate until time t_5, where the center frequency is reset to its low end and shifting begins again.

The next variation in the evolution of spectrum analyzers has no center frequency swept filter. Its filter is a stationary one, and instead of bringing this filter to the frequency of the signal, the signal is brought to the frequency of the filter -- HETERODYNE! Figure 5 shows the block diagram. The input is now fed into a mixer, where it beats with some frequency from a local oscillator.

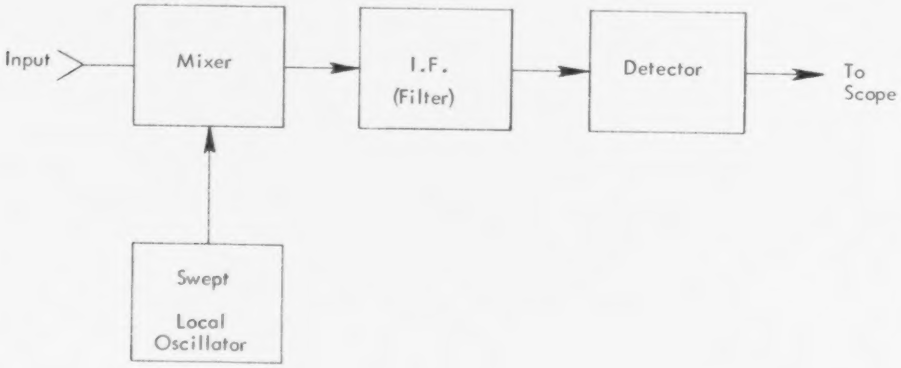


Fig. 5. Front end swept local oscillator version.

Application of the normal super heterodyne equation -- the difference in local oscillator frequency and input signal frequency equals the intermediate frequency --

$$f_{L.O.} - f_{sig} = f_{I.F.}$$

will be used to its fullest. Both the signal and the local oscillator frequencies are varying. The local oscillator is swept over a range of frequencies of the input signal to be analyzed. When the difference is such that it falls in the passband of the I.F., we will see the detected output on the scope.

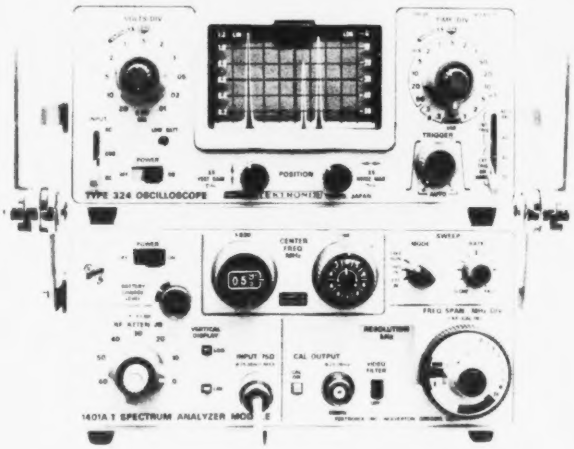
This is illustrated in Figure 6, which shows the relationship between center frequency, frequency span, the sweeping sawtooth waveform and the CRT presentation.

Modern spectrum analyzers can cover frequency ranges from fractions of a hertz to thousands of megahertz and can measure signals from fractional microvolts to many volts in amplitude level. Their applications are literally limitless. For a more detailed discussion of what these versatile instruments can do, we refer you to TEKTRONIX publication number 062-1334-00, "Spectrum Analyzer Measurements, Theory and Practice."

1401A
1401A-1

SPECTRUM ANALYZER

- GATED MODE for PULSED R.F. and TELEVISION
- 75-OHM INPUT (1401A-1)
- 50-OHM INPUT (1401A)
- AC, DC or BATTERY POWERED
- UP to 500 MHz in ONE DISPLAY
- FREQUENCY and AMPLITUDE CALIBRATOR
- 60-dB LOG DYNAMIC RANGE
- INTERMODULATION DISTORTION MORE THAN 60-dB DOWN
- FLAT WITHIN 1.5 dB OVER 200 MHz



1401A/323 Spectrum Analyzer System

The 1401A and 1401A-1 Spectrum Analyzer Modules are an expansion of the plug-in concept of using an oscilloscope for spectrum analysis. These modules, used with the SONY/TEKTRONIX 323, 324, or other oscilloscopes, provide measurement facilities in the 1 MHz to 500 MHz frequency range. The 1401A is designed for 50 Ω systems, the 1401A-1 is for use with 75-Ω systems. Statements about the 1401A apply also to the 1401A-1 unless indicated.

The 1401A and 1401A-1 are compatible with any oscilloscope having 0.5 V/div horizontal deflection factor (adjustable ±10%) and 1.2 V full-screen vertical deflection.

One of the unique features of the 1401A is automatic center frequency positioning in the search mode. At 50 MHz/div frequency span (dispersion), the center frequency automatically becomes 250 MHz, preventing a possible erroneous display. In the search mode, the center frequency control positions a negative marker to indicate that part of the spectrum which will appear at center screen when the frequency span is reduced to less than 50 MHz/div.

Design of the 1401A/323 provides for easy carrying and convenient viewing and access. Power may be obtained from the normal AC line, 6 to 16 VDC, or internal rechargeable batteries.

ANALYZER CHARACTERISTICS

Center Frequency—Continuously selectable with 10-turn digital frequency readout control over the range of 1 to 500 MHz. Absolute accuracy within ±(5 MHz +5% of dial reading). Fine control provides a calibrated variation of up to plus or minus 1 MHz, within 10%.

CW Sensitivity	1401A		1401A-1	
3 kHz Resolution	at least	−100 dBm	at least	−45 dBmV
100 kHz Resolution	at least	−85 dBm	at least	−30 dBmV
1000 kHz Resolution	at least	−78 dBm	at least	−23 dBmV

Frequency Span (dispersion)— 50 MHz/div to 100 kHz/div in 9 steps (1-2-5 sequence), accurate within 10% over a 10 div display, plus 0 Hz span. Frequency span can be continuously varied (uncalibrated) from any calibrated value toward zero.

Resolution Bandwidth— 3, 100, and 1000 kHz.

Display Flatness—Amplitude variations are within 1.5 dB to 200 MHz and 3 dB to 500 MHz.

Incidental FM— 20 kHz or less.

Intermodulation Distortion— 1401A at least 55 dB down with two signals at −30 dBm (+25 dBm 1401A-1), one MHz apart; 60 dB down with signals at −40 dBm (+15 dBm 1401A-1).

Frequency Stability—Within 50 kHz over any 5 minute interval after 20 minute warm-up and measurement at +20°C to +30°C ambient. Temperature coefficient = 0.5 MHz/°C or less.

Input Power	1401A	1401A-1
Maximum with RF attenuation	+30 dBm	+80 dBmV
Without attenuation	30 dBm	+25 dBmV

RF Attenuator— 0 to 60 dB in 10 dB steps (accurate within +0.2 dB + 1% of dB reading).

If Gain Control—At least 30 dB range.

Vertical Display—Linear and log.

Dynamic Range—At least 60 dB in log mode at 10 dB/div.

SWEEP CHARACTERISTICS

Free Run—Sweep rate continuously variable from one sweep per second or less to at least 100 sweeps per second.

External Trigger—Accepts an external positive pulse of 1 to 10 V, at least 100 ns width, 1 MHz or less.

External Horizontal—Input accepts signal of 0 to +5 V. 0 V corresponds to approximately 0 frequency and +5 V corresponds to approximately 500 MHz in Search Mode. 10 V maximum input.

CALIBRATOR

Frequency— 50 MHz within 0.01%.

Amplitude of the Fundamental—1401A, −30 dBm; 1401A-1, +25 dBmV. Accuracy, within 0.3 dB at 25 C and within 0.5 dB from −15 C to +55 C.

1401A
1401A-1

SPECTRUM ANALYZER

OTHER CHARACTERISTICS

Power Sources—Battery operation: removable power pack contains 6 size "C" NiCd cells providing at least 3-1/2 hours operation. Maximum time is achieved at 20°C to 25°C charge and 20°C operating temperature. Internal charger provides for charging the internal batteries when connected to the AC line, operating or nonoperating. Recharge requires at least 16 hours at full charge. A Trickle Charge position prevents battery self-discharge when not in use. Battery charge level is indicated on an expanded scale DC voltmeter. External DC source: operates from an external DC source of 6 V to 16 V, requires 4.8 W. External AC source: operates from an external AC source of 90 to 136 V, or 180 to 272 V; 48 to 440 Hz, 14 W maximum at 115 VAC.

	1401A 1401A-1		323 324		1401A/323 1401A-1/323 1401A/324 1401A-1/324	
	in	cm	in	cm	in	cm
Height	3-1/2	8.9	3-1/2	8.9	7	17.[illegible]
Width w/handle	8-1/2	21.6	8-1/2	21.6	9-3/8	23.8
Depth w/panel cover	10-5/8	27.0	10-5/8	27.0	10-5/8	27.0
Depth w/handle	13	33.0	13	33.0	14-4/8	37.2
	lb	kg	lb	kg	lb	kg
Net weight w/o accessories	7-1/2	3.4	≈ 8	≈ 3.6	≈15	≈ 6.8
Domestic shipping weight	13	5.9	≈14	≈ 6	≈23	≈10.4
Export-packed weight	21	9.5	≈22	≈10	≈31	≈14.0

SPECTRUM ANALYZER MODULE

1401A Included Accessories—8′ power cable assembly; panel cover; blue filter; amber filter; three 5-1/2″, 50 Ω BNC to BNC cable assemblies; 6′ 50 Ω BNC to BNC cable assembly; screwdriver; strap assembly; operator's handbook (1401A); instruction manual (1401A).

Order 1401A

SPECTRUM ANALYZER MODULE

1401A-1 Included Accessories—Same as for 1401A except: Insert for instruction manual; two BNC to F adapters; change 6′, 50 Ω BNC to BNC cable assembly to 6′ 75 Ω BNC to BNC cable assembly.

Order 1401A-1

SPECTRUM ANALYZER SYSTEM

1401A/323 (P7 Phosphor) Included Accessories—Two 8′ power cable assemblies; two panel covers; blue filter; amber filter; smoke gray filter; three 5-1/2″, 50 Ω BNC to BNC cable assemblies; 6′, 50 Ω BNC to BNC cable assembly; two strap assemblies; viewing hood; probe package P6049; BNC to banana post patch cord; BNC to binding post adapter; screwdriver; accessory pack; operator's handbook (1401A); instruction manual (1401A); operator's handbook (323); instruction manual (323).

Order 1401A/323P7
Order 1401A-1/323P7

SPECTRUM ANALYZER SYSTEM

1401A/324 (P7 Phosphor) Included Accessories—Two 8′ power cable assemblies; two panel covers; blue filter; amber filter; smoke gray filter; three 5-1/2″, 50 Ω BNC to BNC cable assemblies; 6′, 50 Ω BNC to BNC cable assembly; two strap assemblies; viewing hood; probe package P6049; BNC to banana post patch cord; BNC to binding post adapter; screwdriver; accessory pack; operator's handbook (1401A); instruction manual (1401A); operator's handbook (324); instruction manual (324).

Order 1401A/324P7
Order 1401A-1/324P7

OSCILLOSCOPE SUMMARY

CHARACTERISTIC	323	324
Bandwidth	DC to 4 MHz	DC to 10 MHz
Risetime	90 ns	36 ns
	10 mV/div to 20 V/div at full bandwidth	
Deflection Factor	1 mV/div at	2 mV/div at 8 MHz
	2.75 MHz	
Input R and C	1 megohm paralleled by approx 47 pF	
Time Base	5 μs/div to 1 s/div	1 μs/div to 0.2 s/div
Magnifier	X10	X5
CRT Display Area	6 x 10 divisions (1/4-inch divisions)	
Phosphor	P7 supplied when ordered with 1401A or 1401A-1	
Amplitude Calibrator	Internal, 0.5 V at external jack	
Power Sources	Internal batteries	Internal batteries
	External 6 to 16 VDC	External 6.5 to 16 VDC
	90 to 136 VAC	115 VAC ±10%
	180 to 272 VAC	230 VAC ±10%
	48 to 440 Hz	48 to 440 Hz
	14 W at 115 VAC	20 W at 126 VAC

The SONY/TEKTRONIX Type 323 and 324 are manufactured and marketed in Japan by Sony/Tektronix Corporation, Tokyo, Japan. Outside of Japan, they are available from Tektronix, Inc., its marketing subsidiaries and distributors.

OPTIONAL ACCESSORIES

Protective Cover—The protective cover for the 1401A or 1401A-1 can be used during transport or storage, and is constructed of waterproof blue vinyl.

Order 016-0112-00

Power Pack—Extra power pack, in addition to the one supplied with the 1401A or 1401A-1, allows one power pack to charge while the other is powering the analyzer. An identical power pack is used in the 323. Pack contains six size "C" NiCd cells and battery charger.

Order 016-0119-02

Adapter—BNC 75 Ω to 50 Ω minimum loss attenuator.
Order 011-0112-00

Battery Set—Set of six NiCd cells.
Order 146-0012-01

7L12
R7403N

SPECTRUM ANALYZER

CHARACTERISTICS

Frequency Tuning Range—100 kHz to 1.8 GHz continuously variable; accuracy ± (10 MHz + 1% of dial indication).

Frequency Span—500 Hz/div to 100 MHz/div in 1-2-5 sequence. 0 Hz (analyzer, not swept) and maximum span (1.8 GHz over 10 div), modes are also selectable. A continuously variable span control is provided.

Calibrator— 50 MHz ±0.01% −30 dBm ±0.3 dB. Harmonics of 50 MHz are generated for frequency span calibration.

Reference Level—Selectable −100 dBm to +30 dBm in 10 dBm steps, a 10 dB variable control is also provided.

Log Display Mode Dynamic Range—70 dB at 10 dB/div; 14 dB at 2 dB/div; log scale accuracy ±0.1 dB/dB, ±1.5 dB maximum over the full dynamic range.

RF Attenuation— 0 dB to 60 dB in 10 dB steps ± (0.2 dB + 1% of setting).

Resolution Bandwidth (6 dB down)— 300 Hz to 3 MHz in decade steps ±20%.

Resolution Shape Factor— 4:1, 60 dB to 6 dB.

Video Filter Bandwidth—Automatically selected by the resolution control.

CW Sensitivity— 110 dBm at 300 Hz Resolution; −108 dBm at 3 kHz Resolution; 100 dBm at 30 kHz Resolution; −90 dBm at 300 kHz Resolution; 80 dBm at 3 MHz Resolution.

Internal Spurious Responses—Less than 100 dBm referred to input.

Intermodulation Distortion—Third order: 70 dB down from two −30 dBm signals. Second order: 70 dB down from two 40 dBm signals (at any frequency span).

Incidental FM—Phase locked Mode: 200 Hz (P-P) maximum; not phase locked: 20 kHz (P-P) maximum.

Display Flatness— ±1.5 dB, with respect to 50 MHz.

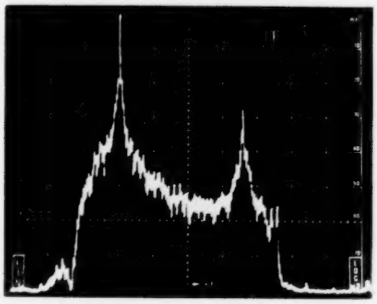
Maximum Safe Input Power—RF Attenuation 0 dB: +13 dBm. (—30 dBm linear operating limit) RF Attenuation 60 dB: +30 dBm (Power rating of attenuator).

Sweep Rate—1 μs/div to 10 ms/div in 1-2-5 sequence continuously variable between steps. Variable control has 100:1 range in 10 ms/div to decrease sweep rate to approximately 1 s/div.

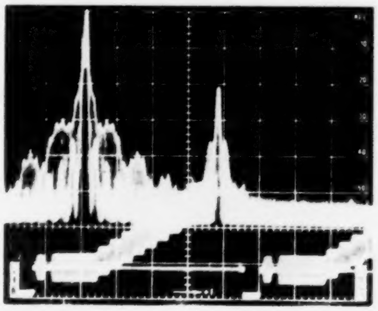
Triggering Modes—Normal, Peak-to-Peak Auto, Single.

Triggering Sources—Vertical Amplifier channels, Power frequency and free run.

DIMENSIONS	in	cm	WEIGHTS (approx)	lb	kg
HEIGHT	5.0	12.7	NET	10	4.5
WIDTH	5.5	14.0	DOMESTIC SHIPPING	13	5.9
LENGTH	14.5	36.9	EXPORT-PACKED	18	8.2



This is the RF spectrum of a television transmitter showing output filter characteristics (pedestal shape) and video, color burst and audio. Frequency span is 1 MHz/div in this display on a 7403N Oscilloscope. Resolution is 30 kHz and the log mode provides 10 dB per div.



The upper display is the RF spectrum resulting from a modulated staircase plus sync and color burst. The lower display is a time base display of the modulated staircase. The simultaneous displays were plotted with a 7A18 Amplifier and a 7B53AN Time Base plus the 7L12 in a 7504 Oscilloscope.

Included Accessories—6-ft BNC cable (012-0113-00); adapter BNC male to N female (103-0058-00); special spectrum analyzer graticules (implosion shields 337-1439-01 for 7403N or R7403N, 337-1159-02 for other 7000 Series); Amber light filter (378-0684-01.

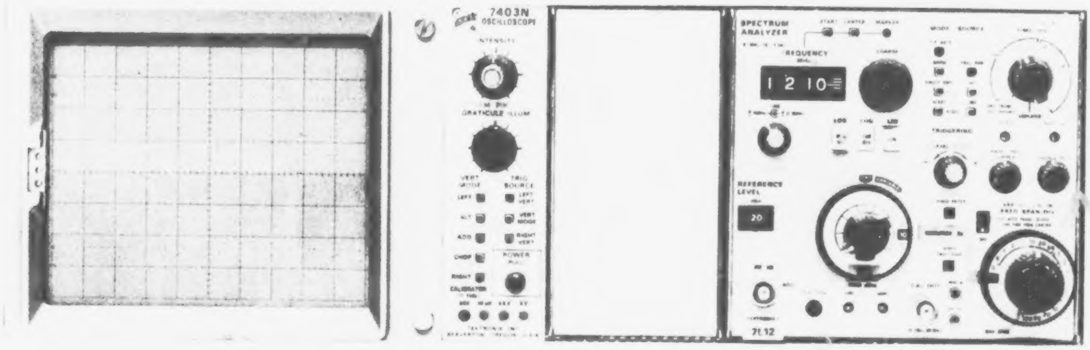
Order 7L12 SPECTRUM ANALYZER
Order R7403N OSCILLOSCOPE

For P7 phosphor and an internal spectrum analyzer graticule.
Order R7403N MOD 08 P7SA

7L12
R7403N

SPECTRUM ANALYZER

- CONVERTS ANY 7000-SERIES OSCILLOSCOPE TO AN EXCELLENT SPECTRUM ANALYZER
- 0 Hz to 1800 MHz IN ONE DISPLAY
- FULLY CALIBRATED DISPLAYS
- 300 Hz to 3 MHz RESOLUTION
- 4:1 RESOLUTION BANDWIDTH SHAPE FACTOR
- 70 dB DYNAMIC RANGE
- INTERMODULATION DISTORTION 70 dB BELOW FULL SCREEN
- SPURIOUS FREE OPERATION
- AUTOMATIC PHASE LOCK
- −110 dBm SENSITIVITY



5¼-inch rackmount R7403N with 7L12 installed.

The 7L12 Spectrum Analyzer Plug-In converts the R7403N Oscilloscope into a high-performance spectrum analyzer. This rackmount system is only 5¼ inches high and is useful in transmitter monitoring and elsewhere in TV spectra measurements.

The 7L12 is a swept front-end spectrum analyzer plug-in for all 7000-Series Oscilloscopes. These run from the rackmounts that are only 5¼ inches high, to 500 MHz real-time bandwidth units. The multiple plug-in concept of the 7000 Series allows simultaneous time and frequency domain displays. 7000-Series mainframes with CRT READOUT will display Reference Level, dB/div, Frequency Span, Resolution and Time/div on screen. All display parameters are calibrated and quantitative information is displayed on both front panel and CRT READOUT. CRT READOUT of display parameters is a unique 7L12 feature.

Excellent resolution shape factor (4 to 1) enables the 7L12 user to measure low-amplitude signals close to full screen signals. The wide, 3 MHz resolution position of the 7L12 enhances narrow pulse spectrum analysis and demodulated waveform measurements.

Much effort has gone into human engineering factors designed to make the 7L12 easier to use and to reduce the chance of human error. A case in point is the three frequency indication modes from which the operator can choose. In the maximum span mode, the frequency dial indication corresponds to the CRT position of a negative-going marker while the analyzer displays the maximum frequency span of 1800 MHz. When the frequency span is reduced, the operator has a choice of two frequency indicating modes, START or CENTER. The former, particularly useful for harmonic and distortion analysis, sweeps with the indicated frequency corresponding to the extreme left hand edge of the display. In the center mode, which is primarily of interest for symmetrical modulation spectra, the center of the display corresponds to the frequency indicated.

Another human engineering innovation is the RF input and reference level self-computing differential mechanism. This mechanism provides direct readout of the full-screen reference level, RF attenuation, and maximum input power for linear operation. Values are presented in dBm on the front panel. The 7000-Series Oscilloscope mainframes with CRT READOUT will also display the full screen reference level value in dBm on the CRT. Further operational ease is provided by color-keyed sections on the front panel.

HIGHLIGHTS
TECHNICAL SESSION

PROGRAM ORIGINATION

Chairman

Jake Landrum
Commco Inc.
Austin, Texas

Speakers

Bernard Wise
CCA
Gloucester, New Jersey

Lyle Keys
Telemation, Inc.
Salt Lake City, Utah

John L. Humphreys
Robert E. Weiblen
National Trend-In Corporation
Reston, Virginia

Frank R. Eldridge
The MITRE Corporation
McLean Virginia

Reporter

Jeseph L. Stern
Goldmark Communications
Stamford, Connecticut

1. "Audio Equipment For CATV" - Bernard Wise

Mr. Wise reviewed the audio input equipment utilized in AM and FM stations and described how they could be applied to CATV systems. He suggested that there is much that CATV operators can learn from the AM and FM station operation that can be profitably applied to cable. Cable operators have to handle sound from integrated sources such as film and tape, as well as separate sound sources required to provide accompaniment to slides, weather-scan presentations and local advertisements. Local program origination also requires somewhat more sophisticated sound control equipment than usually found in a CATV operation.

He described a rationale for equipment selection, covering reel-to-reel and cartridge audio machines, microphones, turntables, portable audio control and turntable packages, and automated pre-programmed reel-to-reel and cartridge ensembles. He pointed out how the automated packages could be used to provide unattended background music services, automated insertion of advertising messages and general background for isolated video presentations.

2. "The T-Matic Videocassette Program Automation System" - Lyle Keyes

Mr. Keyes presented a full description of Telemation's fully automated 3/4" video cassette playback system called "T-Matic." This unit automates the operation of four or five Sony videocassette players permitting unattended programming of both audio and video for at least four hours on its own, or for much longer periods if the unit is used in conjunction with a non-duplication switching system. In this case, the T-Matic will provide the insertion of programming when the air channel is deleted.

The T-Matic unit can control its own program sources as well as a number of external sources such as reel-to-reel tape machines or projectors. The logic in the machine controls the start and stop, cueing and rewind of the cassette video players to provide continuity. Video and audio switching of all four players plus one external source is also provided. A cueing scheme is also provided to allow one of the players to insert advertisements into program material in a fully professional manner, fully unattended.

3. "Discable - A New Automatic Sound and View Programming System For CATV" - John L. Humphreys and Robert E. Weiblen

Messrs. Humphreys and Weiblen described a system for providing an FM audio programming service on cable, using the FM band for the distribution of up to fifty stereo or quad channels, and using one video channel for annoucing the audio service and for the display of supporting advertising material.

The audio material is recorded on a proprietary tape machine, utilizing 1/2" audio tape capable of providing 12 hours of programming. In the recording process a mini-computer is used to provide identifying tapes that are keyed to announcements and advertisements which are automatically presented to the system by a character generator. The end result is a presentation on the TV screen of the FM channel number, the name of the selection being played, the record ordering information and the names of the upcoming selections. This is displayed for thirty seconds and the sound channel carries the audio being advertised. The bottom half of the screen can carry character generator advertisements of a presentation from a viedo source, in color or monochrome.

4. "Privacy For Cable Services" - Frank R. Eldridge

Mr. Eldridge reviewed the work that has been in progress to develop new cable services and pointed out the many problems of providing privacy for a large number of these services. Many of the proposed services such as mail delivery, credit checks, access to files, etc., will need a high degree of privacy that does not appear to be available with many of the proposed systems which carry all of the information to all parts of the cable system.

He displayed block diagrams of a terminal system developed by MITRE with addressing and selective gating, allowing only the approved recipient to have access to a private channel; but, in this case, he proposes that only the control keyboard and display units be available in the subscriber's location. All active interrogation, addressing and gating electronics are to be located outside the home, either in a local distribution center, on a pole or strand or in an underground housing.

5. "VTR's - Trade-Offs, Compatabilities and Problems"

Mr. Keys substituted for Mr. Hymas and reviewed the video tape recorders and players available to the cable operators, their advantages and disadvantages. Among the major problems with slant track machines, he pointed out that the lack of time base stability presents the possibility of "flagging" on many home receivers due to the receiver's long time constant horizontal AFC circuitry. Potential buyers of equipment were warned not to observe the output of these machines on video monitors or short time constant receivers or they will not truly see what might happen to a large number of receivers on their system.

The variety of systems, their incompatibility and performance were discussed. It was suggested that the widespread use of videocassetts will soon overcome the interchangeability problem, and these units will probably be so universal as to create a standard format. When selecting video tape equipment, the audience was warned to analyze the specifications, compare them to their needs, and to check carefully to see if the offered equipment is merely in prototype, or is really in manufacture.

AUDIO EQUIPMENT FOR CATV

Bernard Wise
CCA Electronics Corporation
Gloucester City, N.J.

CATV has come of age. The combination of normal aggressiveness on the part of CATV operators together with FCC suggestions towards origination of programming has motivated CATV technical personnel to update their technical facilities to incorporate the latest techniques in both visual aural production and reproduction equipment.

The purpose of this presentation is to summarize the conventional audio techniques that are being utilized in the AM-FM broadcast industries and noting their application in the CATV industry.

CCA Electronics is one of the leaders in the manufacture and distribution of AM and FM broadcast and studio equipment. The purpose of this presentation is to familiarize the CATV operator with the state of the audio art in the AM - FM area with the hope that possibly these techniques are applicable to your area.

Audio equipment for CATV must be classified into two general areas. The first area relates to programming material in which both the audio and video are non-separable from each other. For example, this is true in the area of films and video tape in where both the aural and the visual intelligence is on the same program source. The second general classification of audio equipment for CATV can be described as that type of programming in which the video and audio are separable from each other. This can be exemplified in the production area where slide and separate audio sources may be used as background for the slides.

Figure 2 describes a representative block diagram of the first class of audio equipment, namely the non-separable audio-visual programming. Here you will note that a conventional switcher is used to serve as the master control between three representative program sources. Video switchers are designed today to incorporate the feature of audio follow. However, in many installations the audio rather than being fed directly from the video switcher to the transmitter is fed to an audio console in order to obtain additional master control.

Figure 3 is representative of an audio control center for CATV with suggested audio sources relating to CATV production and on air programming. Here you will note that a master audio console with six independent channels is used to mix, fade and control the audio sources from six independent program sources. The output of this audio console is fed through appropriate compressing and limiting equipment to the transmitter as well as to the monitor, audition outputs and cue outputs. The balance of this presentation will relate to the various audio equipments described in this block diagram with the purpose again, of summarizing the existing techniques that relate to these various audio sources.

Reel to Reel Tape Equipment (Figure 4)

There exists a host of reel to reel tape equipment that do have application in CATV operations. It is our suggestion that before selecting a reel to reel tape machine that the following considerations be given:

Playback or Record Play: It is not necessary to have a combination record/play unit in every studio. Many broadcasters find it more economically attractive to utilize only playback machines in the programming studio and utilizing a combination record/play device in the production area. In addition to the economic saving, it tends to prevent inexperienced operators from erasing valuable program material.

Reel Capacity: Tape machines are available with many reel capacities. The most popular size is the tape machine with the capability of handling $10\frac{1}{2}$" reels. A $10\frac{1}{2}$" reel with 1 mil mylar is capable of storing $1\frac{1}{2}$ hours of tape when operating at $7\frac{1}{2}$" per second and 3 hours of tape when operating at 3 3/4 IPS. It is important to know the time capacity required for your operation in order to be sure that you do not purchase a reel to reel tape machine without adequate size.

Speed Requirements: The frequency response requirements of CATV are not as stringent as stereo FM, and thus, the speed capacity of the reel to reel tape machine should incorporate the features of 3 3/4 IPS and $7\frac{1}{2}$" IPS. The former could be used for local program origination and to be sure of substantial capacity, while the fact that it does have the facility for playing back $7\frac{1}{2}$ IPS would permit the reel to reel tape machine to be used with playing back sources recorded at external production areas in which this more popular recording speed might have been made.

Mounting Requirements: Reel to reel tape machines are available in various mounting formfactors. The two most popular formfactors are 19" relay rack mounting, while the second is a conventional desk top mounting. For proper utilization of your facility it is important that the device you purchase is capable of fitting the formfactor of your physical arrangement. Some desk top units cannot be rack mounted.

Number of Tracks: Since CATV operation is monaural in nature, there may appear to be little reason for using tape machines other than full track. However, since so much material is recorded in stereo, it is suggested that careful consideration be given to purchasing a two track device with facilities of combining both the left and the right to obtain a monaural output. In addition, the second track can be used as a cueing source or additional control channel. The utilization of two track reel to reel tape machine for monaural operation does very little in practice, to affect the signal to noise of the system.

Cost: Professional, reliable, high quality reel to reel tape machines are available in both the record/play and the playback formfactor at selling prices of $700 to $3, 000. It is important that the optimum compromise be made between cost and utilization in selecting your reel to reel tape equipment.

Audio Cartridge Equipment: The endless tape cartridge utilized in broadcast audio cartridge equipment has proven itself to be the most reliable, highest quality program source for commercials and short program material. It has tremendous application where flexibility and reasonably fast access is required. In broadcast operation it appears at present, that audio cartridge equipment represents the most important audio program source in a broadcast facility. When purchasing audio cartridge equipment, it is suggested that you make the following considerations:

Playback or Record/Play: Generally, it is not necessary to invest in many Record/Play devices. One or possibly two record/play units for production is more than adequate, while two or three playback cartridge machines generally will meet the normal requirements of a CATV studio operation.

Cartridge Capacity: There exists three standard cartridges. The more popular cartridge, the series 300, has a maximum time capacity of $10\frac{1}{2}$ minutes. The 600 and 1200 series can achieve capacities of 31 minutes. There has been recently a number of cartridge machines introduced which are designed only to accept the smaller cartridges. They are very compact and three units, whose width is less than 5 3/4", can be used in a 19" rack. If the larger cartridges are intended to be used in your CATV operation, these smaller cartridge machines will not be as attractive. Therefore, it is important to know the cartridge requirements you will have in your CATV operation.

Auxiliary Tones: Cartridge machines are available with additional options which include secondary and tertiary control generators and detectors. These tones are generated and recorded on the control track and may be used to obtain an extremely fast format with back to back cartridge plays by having these auxiliary tones triggering other machines. Thus, while the first cartridge machine is playing to its original cue position, the other machines in the operation may be automatically turned on by the auxiliary tones on the cue tracks. If this is the ultimate application of your facility, it is important that the cartridge machines that you purchase either incorporate the auxiliary tones or have the capability of having these tones installed at a future date.

Operational Features: Machines are available with various operating controls. The older style units incorporated lever type actions before the cartridge could be installed and set for operation. Newer units are available in which just the application of the cartridge in the machine turns on the start motor and has the device ready for instant operation. Depending on your application, one particular formfactor may have an advantage over the other.

Cost: Monaural playback machines vary in cost from $395 to $795. A combination record/play unit sells for approximately $200 more than the playback only machine.

Microphone Equipment: A host of microphones are available for the CATV industry. The considerations that should be given before selecting a microphone are suggested to be as follows:

Pattern Requirements: The most important requirement of a professional microphone is that the pattern of the microphone is consistent with the application. If the microphone is intended for close-up operation, a specific pattern and sensitivity should be used. On the other hand, if there exists noise in the recording studio or operation plant, a directive pattern could substantially reduce the effect of this noise. A microphone intended for a group activity should have an omni-directional pattern. The pattern of a microphone is extremely important.

Impedance: Microphones are available with both low and high impedance. To reduce the complexity of the overall system it is suggested that the low impedance balanced microphone be used. This tends to reduce the complexity of station installation and many times eliminates the requirement for custom matching transformers.

Cost: Professional microphones with the frequency response and fidelity necessary for CATV are available at the professional user's cost from $50 to $200. A host of microphones are available in each and every operators requirements.

Turntable Equipment: CCA's subsidiaries QRK and Rek-O-Kut are two of the major manufacturers of turntable, tonearms and turntable accessories. As a result of our experience in this area, we recommend that before purchasing turntable equipment that you make the following considerations:

Instant Start: We feel that it is important that a professional CATV operation have a turntable which after the application of the start switch achieves its final speed within a very minimum time. Turntables are available which can achieve its final speed in less than 1/6th of a revoluation.

Reliability: Many turntables are being used in the CATV industry which are manufactured for the consumer industry. Although these turntables are very useful in the Hi-Fi area, the ruggedness required for professional use insists on the fewest number of moving parts and trouble-free operation. The simplicity of professional turntables is such that the majority have no more than three moving parts. These units can be expected to operate trouble-free for many, many years, with a minimum of maintenance.

Preamplifier "Head Level": It is important when considering the purchase of preamplifiers for turntables that one purchases a preamplifier with sufficient head room such that when there is a very loud passage on the record, that the electronics has sufficient head room to pass this loud passage without "flat-topping" and introducing distortion. Preamplifiers are available such that flat-topping does not occur until at least +10 dbm is achieved. This is approximately 30 db more than the normal -20 dbm output required of conventional turntable preamplifiers.

Record Wear: With the advent of Hi-Fi stereo and the extremely high expense of these records, it is imperative that tonearms and cartridges be used which not only can reproduce these records, but also not destroy these records. Tonearms in the past which incorporated viscus damping had a tendency to require substantial loading to assure tracking. It is recommended that tonearms which require a maximum of 2.5 grams be used with present day state of the art records. Under this loading little record wear, if any, will be affected by the tonearm.

Cost: Turntables are available to meet the stringent requirements of CATV operation from $175 to $200. Tonearms are available from $50 to $75. Preamplifiers are available from $150 to $175, and appropriate furniture to meet the requirements of the application from a table tope base at $25 to a free standing furniture with record storage capacity at $150.

Automation Equipment:

Perhaps the major advance in audio in the broadcast field has been in the area of automation. There exists today a number of field proven automation equipment packages which can achieve unattended, flexible operation for your CATV operation. However, since so many formfactors exist, it is imperative that careful considerations be given of your program requirements before selecting automation equipment. We suggest that you investigate the following:

Format Requirement: First analyze what the application of your equipment will be. It is important that you also understand what variations you may possibly introduce in the event that your format requires modifications. The equipment that you consider must be capable of having this flexibility.

Access Requirement: It is imperative that the automation equipment that you purchase have the facility of access consistent with your requirements.

Priority Requirement: In many program formats, it is necessary to interrupt the normal sequence of events on a time or a priority basis. In some program formats the interruption is only done on an hour and half hour basis for station identification. In others it is done with some frequency to introduce spots. However, it is important that whatever equipment you purchase has the capacity to accept the number of inter ruptions of the normal preset sequence approach consistent with your requirements.

Unattended Time Requirement: The function of an automation system in addition to providing management with absolute control is hopefully, to reduce the cost of personnel operation. Thus, it is important to understand the requirements for unattended operation of your facility. This in turn would influence the time capacity of the automation equipment that you are seeking.

Expansion: It is important that you carefully consider automation equipment which not only will provide your immediate requirement but also have the facility for being expanded at a future date without superseding the existing equipment.

Cost: Automation equipment is available at realistic prices as low as $6, 000 and as high as $50, 000. The Mini Automation described in Figure 8 which incorporates a 24 cartridge carousel, two reel to reel record/playback tape machines, and one outboard cartridge playback machine with 150 cycle detection and of course, the master four source brain is available through CCA Electronics at $6, 300.

Audio Consoles:

The heart of your complete audio facility is the studio console. The purpose of this console is to switch, fade and control all of the audio sources in your facility. Pictured in Figure 9 are two representative audio consoles. The first is the CCA "Futura Six", a Six Channel, modern audio console with slide faders and facilities for cue, monitor and audition in addition to the normal program channel. The second unit is the popular Shure M67 Mixer. Both of these units or variations thereof have applications in a CATV system. It is suggested that before purchasing an audio console that you investigate the following considerations:

Capacity: Each CATV operation has a different number of audio sources. Each CATV operation has a different modus of operandum. Some organizations require independent controls for each of their program sources. Some operations would be content to have three sources being applied to the same channel and switching between the three sources. There are commercially available audio consoles with facilities from six to twenty independent audio channels. Each of these audio channels may have as much as three to five audio inputs. Thus, it is possible to have control of as many as eighteen to one hundred audio sources.

Cue, Audition, Monitoring: If it is required to cue, audition and/or monitor programming in addition to the normal function of mixing, fading, etc., it is important that you consider conventional, professional broadcast audio consoles. If these requirements are not necessary for the application, conventional audio mixers as exemplified by the Shure Mixer could more than do the application.

Mechanical Requirements: It is important that the unit meet the physical requirements of the CATV scene. For example, at remote locations or "man in the street" operations where mixing and fading of various audio sources are required for recording or for relay, it might be preferable to use lightweight, battery operated Shure Mixer than the more prestigious, bulky "Futura Six" audio console.

Cost: Audio consoles vary from the $150 of the Shure Mixer to the $1,000 of the CCA Futura Six to the $5, 000 CCA Automatic Ten console. Within this range there exists a host of audio console formfactors, one of which can meet the requirements of your CATV facility.

Figures 10 and 11 refer to CCA prewired audio systems. In Figure 11 we have a prewired turntable audio console microphone all mounted on transportable furniture. This unit can be set up and installed in operation in a matter of minutes. It has Cannon plugs on its skirt to which can be connected conventional audio program sources. This unit is ideal for local originations at athletic events or for rapidly setting up a studio or production room. This unit sells for less than $2, 000. The more complex prewired system pictured in Figure sells for approximately $7, 000 and in addition contains substantial furniture, a more sophisticated audio console, a dual turntable system and a dual cartridge system. It is also prewired and has facilities for plug-in program sources. Obviously, this system is not transportable, but it can still be installed and set up in an operating area within several hours.

In summary, I am sure that all knowledgeable industry personnel recognize the importance of having a flexible, reliable and professional audio facility as an intrigal part of every CATV operation. I trust that this presentation will provide you with an introduction to the present state of the field proven audio program equipment and systems for the broadcast and CATV industry.

Thank you.

CLASSIFICATIONS OF AUDIO EQUIPMENT FOR CATV

CLASS Nº 1 – NON-SEPARABLE AUDIO/VIDEO
ie. - Films, Videotape

CLASS Nº 2 – INDEPENDENT VIDEO AND AUDIO
ie. - Production, Slides, Weather Channel

FIGURE I

AUDIO BLOCK DIAGRAM OF NON-SEPARABLE AUDIO/VIDEO (CLASS Nº I)

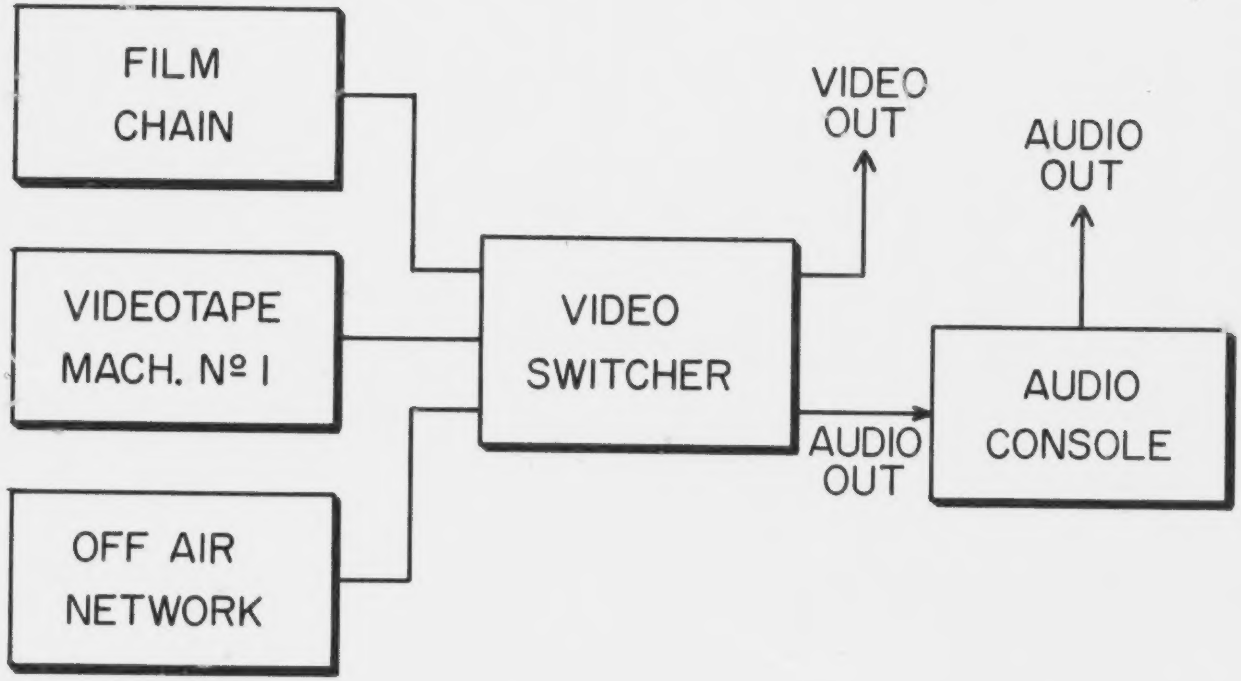
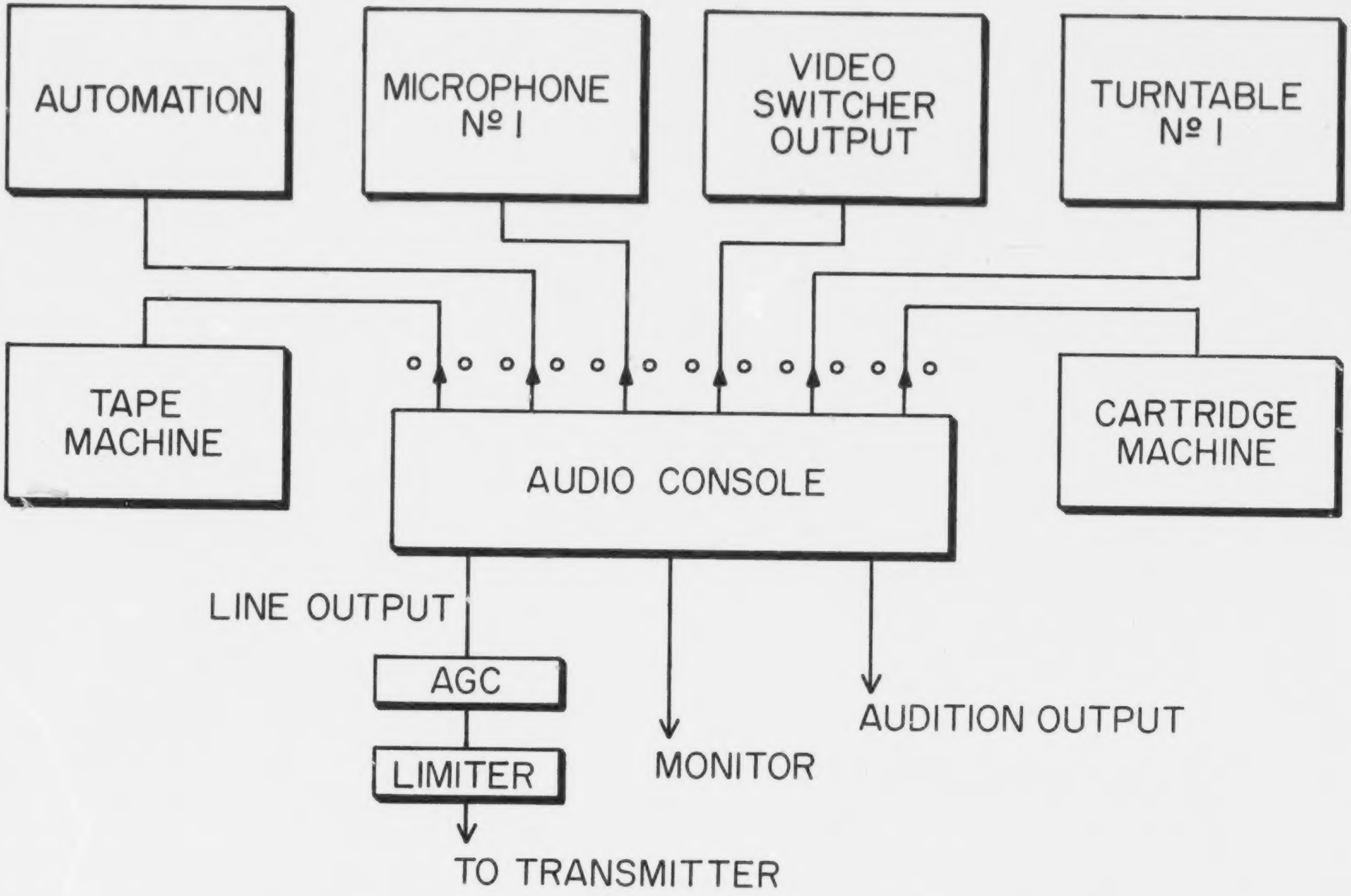

FILM CHAIN
VIDEOTAPE MACH. Nº I
OFF AIR NETWORK
VIDEO SWITCHER
VIDEO OUT
AUDIO OUT
AUDIO CONSOLE
AUDIO OUT

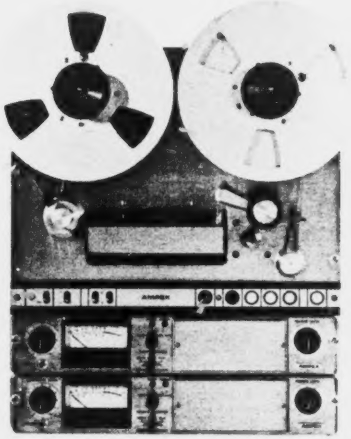
FIGURE 2


AUTOMATION
MICROPHONE Nº I
VIDEO SWITCHER OUTPUT
TURNTABLE Nº I
TAPE MACHINE
CARTRIDGE MACHINE
AUDIO CONSOLE
LINE OUTPUT
AGC
LIMITER
TO TRANSMITTER
MONITOR
AUDITION OUTPUT

AUDIO CONTROL CENTER FOR CATV

FIGURE 3

REEL TO REEL TAPE EQUIPMENT

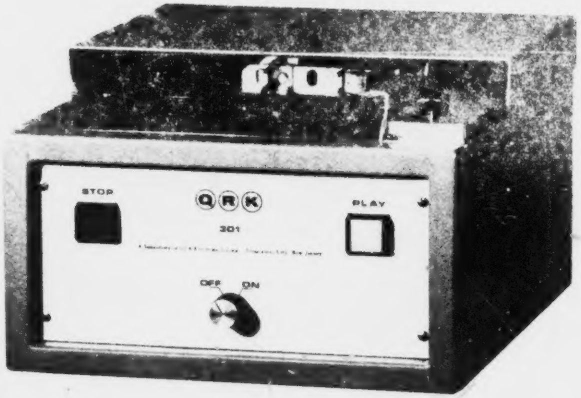


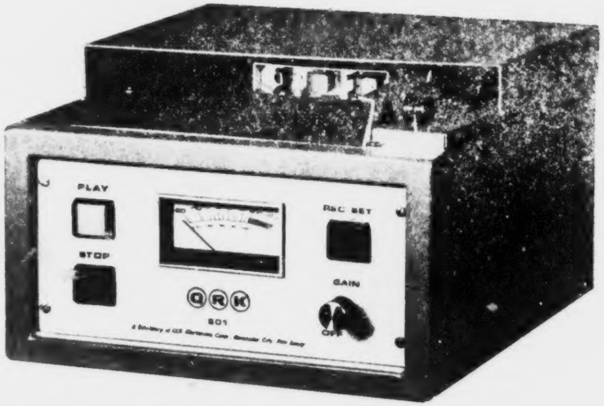
CONSIDERATIONS

- PLAYBACK OR RECORD/PLAY
- REEL CAPACITY
- SPEED REQUIREMENTS
- MOUNTING REQUIREMENTS
- Nº OF TRACKS
- COST

FIGURE 4

AUDIO CARTRIDGE EQUIPMENT


STOP
QRK
301
PLAY
OFF
ON


PLAY
STOP
QRK
801
REC SET
GAIN
OFF

ENDLESS TAPE

SELF CUEING

RELIABLE

BROADCAST QUALITY

CONSIDERATIONS

- PLAYBACK OR RECORD/PLAY
- CARTRIDGE CAPACITY
- MECHANICAL FORM FACTOR
- AUXILIARY TONES
- OPERATIONAL FEATURES
- COST

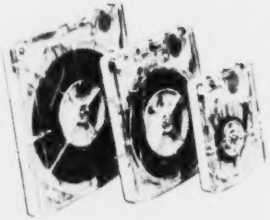


FIGURE 5

MICROPHONES

CONSIDERATIONS

- PATTERN REQUIREMENTS FOR
  - REMOTES
  - CLOSE-UPS
  - GROUPS
- IMPEDANCE
- COST

FIGURE 6

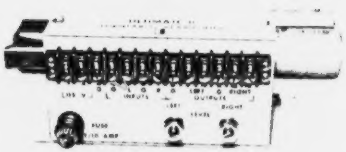
TURNTABLE EQUIPMENT

TURNTABLES

TONEARMS

CONSIDERATIONS

- INSTANT START
- RELIABLE
- HEAD LEVEL
- RECORD WEAR
- COST

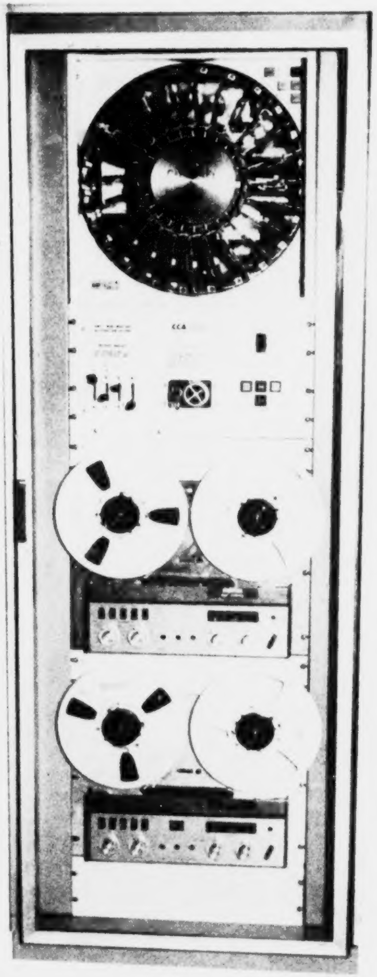


PRE-AMPS

FURNITURE

FIGURE 7

AUTOMATION EQUIPMENT

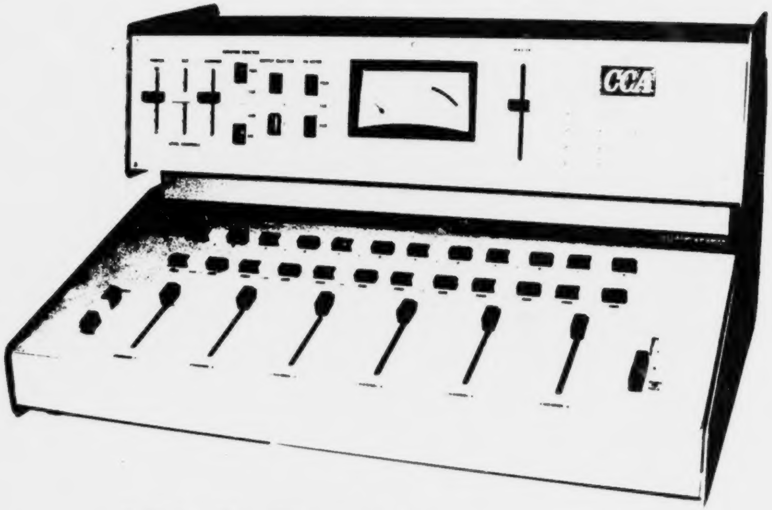


CONSIDERATIONS

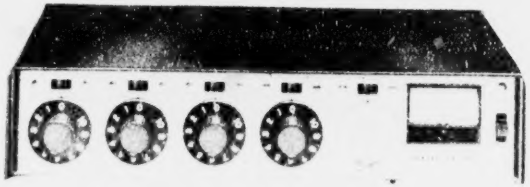
- FORMAT REQUIREMENTS
- ACCESS REQUIREMENTS
- SEQUENCE REQUIREMENTS
- PRIORITY REQUIREMENTS
- UNATTENDED TIME REQUIREMENTS
- COST

FIGURE 8

AUDIO CONSOLES



CCA FUTURA 6



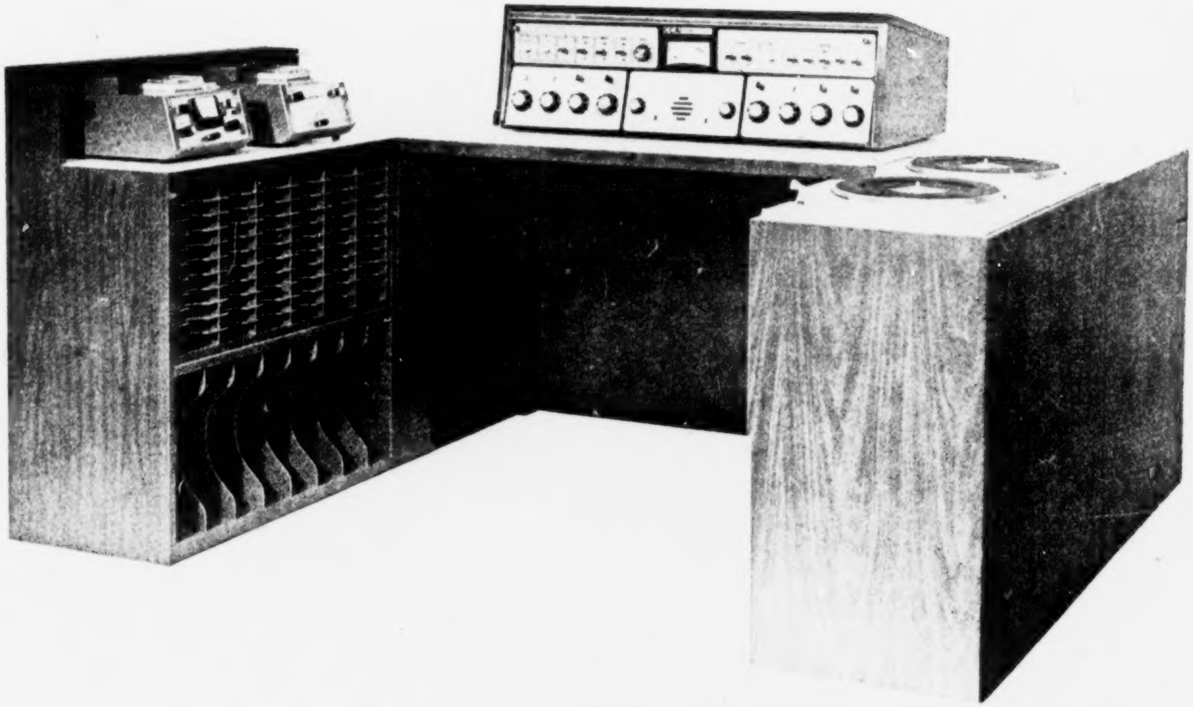
SHURE MIXER

CONSIDERATIONS

- CAPACITY REQUIREMENTS
- REQUIREMENTS FOR CUE, AUDITION AND MONITORING
- MECHANICAL REQUIREMENTS
- POWER LINE REQUIREMENTS
- FLEXIBILITY
- COST

FIGURE 9

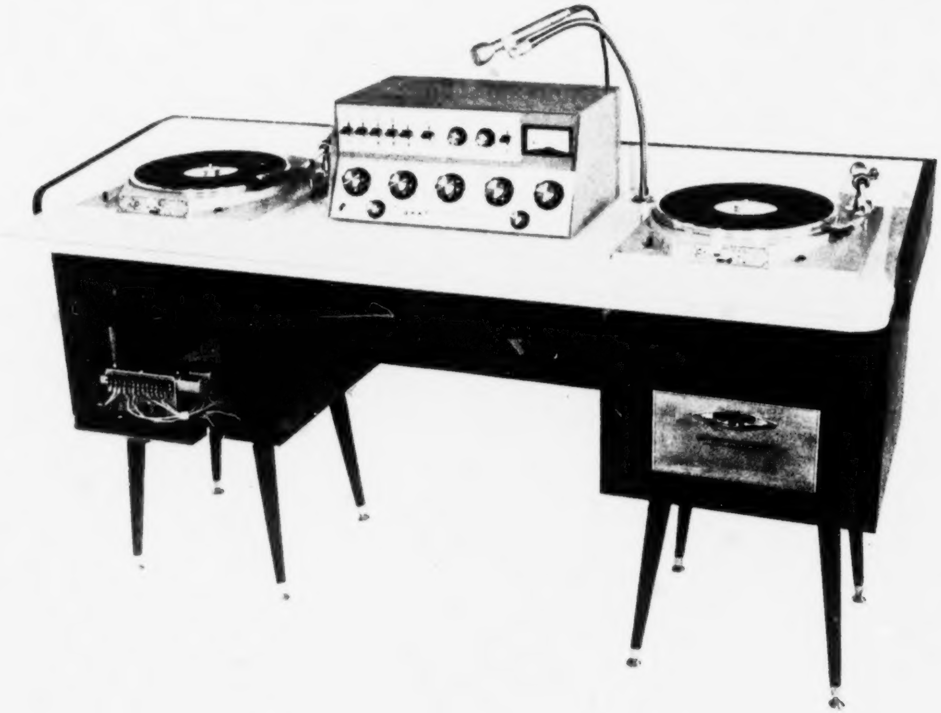
CCA PRE-WIRED AUDIO SYSTEM



$7,000 APPROXIMATE

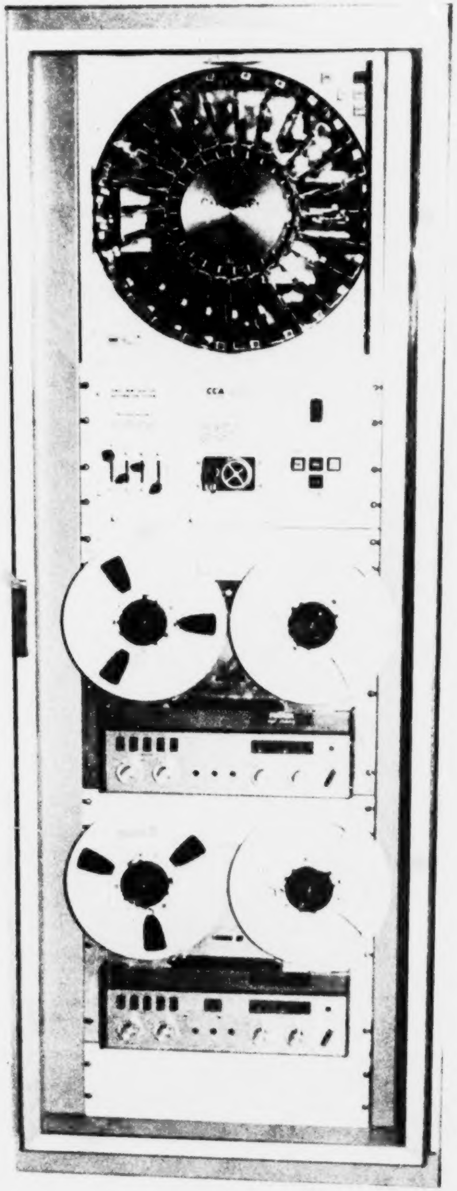
FIGURE 10

CCA PRE-WIRED AUDIO SYSTEM



$2,000 APPROXIMATE

FIGURE II



BACKGROUND MUSIC

CONSIDERATIONS

- FORMAT REQUIREMENTS
- UNATTENDED TIME REQUIREMENTS
- NON REPETITIVE REQUIREMENTS
- COST

FIGURE 12

THE T-MATIC™ VIDEOCASSETTE PROGRAM AUTOMATION SYSTEM

Lyle O. Keys, President, TeleMation, Inc.

The potential for local origination in CATV is almost limitless. With multiple channels available and few constraints on the manner in which these channels are utilized, cable systems could originate many hundreds of hours of program fare per week. When compared to this potential, local origination to date has been a failure, the principal reason being economic factors. These economic factors can be defined by three letters—"CPM"—the advertiser's jargon for cost per thousand viewers. The cost of program fare has been tied to broadcast stations who typically serve ten to one-thousand times as many sets as cable systems in the same market. The cost of local origination equipment, while lower for cable than for broadcast, is still high when viewed on a cost-per-thousand basis. Most significant are the operating costs. Cable systems, if they are to be competitive, have to employ the same quantity and type of personnel to program a single cable channel as a broadcaster requires to program his channel. Again, on a cost-per-thousand basis the cable operator's expenses are sky high.

Times are changing. The software owners, to whom cable was just a dirty word two years ago, are at this convention in force anxious to capitalize on what they know will be a lucrative new market for them. It's a safe bet that the cost-per-thousand to the cable operator will be significantly reduced as competition for his dollars heats up.

My talk today involves developments that will affect the other two economic factors mentioned, equipment costs and operating costs.
The recent development and introduction of the Sony U-Matic videocassette equipment is the key factor in reducing these costs. At $995, the videocassette player is less costly than any previously available color videotape equipment, while in terms of picture quality it is more nearly comparable to open-reel machines in the $4,000 to $8,000 price range. These cost and quality considerations plus the very enthusiastic acceptance that this format has received to date tell me that the 3/4" cassette will substantially replace 16 mm film as the principal duplication and distribution medium for entertainment software in our industry. This means that instead of tying up a $20,000 film chain running a $400 print that becomes unusable after 15 showings to program a single channel, the cable operator will be able to offer multiple channel programming using $995 decks with per-run print costs measured in pennies rather than dollars.

Two down and one to go. The videocassette reduces the equipment cost and the print cost but someone still must load, pre-cue, start, stop, and rewind the machines. Someone also has to switch audio and video; and, since a reasonably professional transition from one program source to another requires that all of these things be done at once, that someone is more likely to be two someones.

FM stations a few years back found themselves in a similar situation, squeezed between limited revenues and high operating costs. They were saved from economic disaster by a concept known as program automation. FM broadcasters that recognized the wisdom of spending $40,000 to $80,000 to convert to unmanned operation are generally alive and well today.

TeleMation has developed a program automation system analogous to those used by FM stations except that this system was developed for the CATV industry and does its thing in living color television rather than audio only. Its price, instead of being $40,000 to $80,000, is more like $5,000 to $10,000. We call it the T-MATIC™ Program Automation System. We believe it embodies the necessary features to permit continuous unattended programming of better quality and in a more professional manner than is generally provided by manually operated systems. It provides automatic pre-cueing, starting, stopping, rewinding, and program switching between any number of Sony U-Matic players or between its own players and external program sources. Features such as digital tone decoding, solid state audio and video switching, automatic pre-roll to attain machine lockup prior to switching, and a selection of various internal and external transition modes permit a quality and continuity of programming approaching broadcast standards.

This slide shows the T-MATIC console. It is equipped with lockable front and back doors to permit its being located in public access areas. The cabinet is pressurized with filtered air to minimize dust problems that would shorten head and tape life. The next slide shows the console with the front door open. Four tape decks can be mounted in the cabinet. The control panel mounts at the top, while 10½" of rack mounting space is provided in the bottom to permit installation of modulators or other equipment. Casters are provided to facilitate rear access while using a minimum of dedicated floor space.

The next slide is a view of the control panel. The group of switches on the left are for event control, the next group are for machine selection, and the last group are for program switching. The switches and indicators in each horizontal row are associated with a single event—an event being a transition from one program source to another. At the far left in each event row is a SKIP switch. When a SKIP switch is depressed, its event is removed from the sequence. In installations involving only two or three players, SKIP switches are used to limit the number of active events to those required to sequence between the machines and/or program segments actually used.

Before describing the mode selection switches I will digress for a moment and discuss the concept of cueing. Cue signals are tones placed on one of the two audio tracks to accomplish the following tasks:

1. Pre-cue tapes at the time the machines are loaded.
2. Pre-roll machines to achieve servo and color lock-up prior to airing.

3. Switch audio and video from one machine (or external source) to another.

4. Stop machines after completion of a program segment.

5. Rewind machines after the last segment on each reel is played.

6. Pre-cue tape to start position after rewind is completed.

7. Insert commercial or promotional announcements at appropriate breaks in the program material with all of the machine control and program switching functions handled automatically.

The T-MATIC system uses three cue tones to accomplish these tasks:

> The START cue is placed at the beginning of each reel. Its principal use is to pre-cue the tape to the start point when initially loaded or following the automatic rewind cycle. It is placed four seconds before actual start of programming to provide adequate time for machine lock-up prior to program switching.
>
> STOP cues are used where a tape is to be interrupted but not rewound. STOP cues are placed on the tape four seconds prior to the actual stopping point to permit pre-roll of the next source.
>
> END cues are recorded four seconds before the end of the last program segment on each reel. The END cue performs the same starting, stopping, and switching functions as the STOP cue. In addition it causes the tape to be rewound and re-cued ready to be aired again.

There are six switches associated with each event to determine the source and mode of program transition. The first three permit selection between the START, STOP, and END cues picked up from the machine in play. The last three buttons permit control from various external sources such as a live studio, non-duplication programmer, or from other T-MATIC consoles. Selecting any one of the six controlling sources locks out all others—Thus the operator can select the right transition mode even though there may be more than one cue tone at a program break.

The programmer provides for six actual events (numbered 1-6) and one virtual event, which we label "the reversion event." The reversion event has been incorporated to permit repetitive insertion of material, generally promotional or commercial announcements from a single machine with programming reverting to the previous event in play upon completion of the announcement. Without this reversion capability it would be necessary to use up two of the six events for each announcement inserted. With the reversion feature, the six events are preserved for transitions from one program machine to another or between external sources and the T-MATIC system. The transitional mode between the program deck and the reversion deck is determined by two sets of switches. Normally STOP cues are used for both entering the reversion mode deck and returning to the program deck.

The reversion enable switch associated with each event permits the operator to override the reversion mode. If the reversion mode is not enabled, programming sequences to the next unskipped event upon sensing the selected cue tone.

The manual take switches can be used to preset or override the event counter. These switches can also be duplicated remotely to permit external manual or machine control of the system.

The next event and event-in-play lights provide a quick visual check of the system status.

The machine selection buttons permit full machine assignment flexibility. Up to five sources can be handled by the system. In most configurations these sources will consist of up to four videocassette decks plus one external source.

The two rows of vertical switches on the right control the program and monitor switcher busses. Program switching is normally handled automatically by the programmer so this switch will be used only for emergency operation where direct manual access to a given machine is required. The video and audio outputs from the monitor switcher normally go to a monitor mounted on top of the console. This switch permits monitoring any of the decks while off-line for checking program material without interrupting the on-air operation. A sixth position of this switch permits continuous monitoring of the program line out. Video test points are provided at the output of both switcher busses, while a switchable VU meter permits monitoring of either program audio as selected by the program or monitor switcher bus or cue channel audio as selected by the monitor switcher bus.

The next slide is a rear view of the console showing the electronics card cage. The next slide shows the card cage by itself. All of the active electronics are mounted on these circuit boards. A board extender is included with the system to facilitate servicing the electronics while in operation. Reading from left to right, the first five circuit card slots accommodate either Machine Control Modules or External Control Modules. The picture shows four Machine Control Modules and one External Control Module installed. Each Machine Control Module provides AC power to its associated deck. The control cable connects to the

Control Remoting Module attached to the front of the machine for operating the PLAY, STOP, and REWIND keys. Normally only two of the audio input jacks are used, one for program and one for cue audio. The third audio jack is in anticipation of stereo applications where, by means of an external filter, the cueing signals can be separated from the program material. The terminal board on the External Control Module provides connections for cueing and control signals to and from other T-MATIC consoles or external controls and sources. Video and audio from the external sources are switched to the program output line when the external source is selected by the programmer. Next is the output amplifier card providing both program and monitor audio and audio and video outputs. The master logic circuit card contains the various counting and timing circuitry required for the programmer. The last four slots accommodate event control cards. Each of these cards contains the logic circuitry associated with three events. The normal configuration provides for two cards controlling six events. The two remaining slots would allow for the addition of two more Event Control Modules. These additional modules along with an event expander panel would increase the system's capability to 12 actual plus one virtual event. The expander panel is not yet available and will only be manufactured based on a demonstrated need for event expansion.

The terminal strip along the bottom of the card cage permits external control of individual events. The next series of slides shows the electronics modules removed from the card cage. First is the Machine Control Module. It provides power to the cassette machine and includes the logic and driving circuitry for the remote operation of the machine controls. It incorporates tone sensing and five video and audio switcher cross points. The next slide is the External Control Module. Next is the video and audio amplifier card. The next slide is the master logic card. It incorporates all of the electronics except that which is peculiar to either machine control or event control. Next is the Event Control Module.

The next slide shows the Sony VP-1000 Videocassette Player. This player, in addition to providing good color reproduction, is expected to be very reliable in CATV applications. This expectation is based on extensive life testing recently completed by a major industrial concern, and the cassette concept eliminating a major source of equipment failures by reducing mistreatment during loading and unloading operations. Another feature of the Sony machine that makes for ease of automation is its automatic end-of-tape sensing at both the beginning and end of the tape. The machine is, in fact, ideal for incorporation in an automation system, except in one regard—it is not designed for remote control. The keys that control the fast forward, play, stop, and rewind functions perform many mechanical as well as electrical functions, therefore making it impossible to convert the machine to remote control through electrical modification only. This fact plus our desire to leave the basic machine unchanged led to the development of the T-MATIC Control Remoting Module.

The player is shown with the T-MATIC Control Remoting Module installed. The next slide shows it with the cover removed. The next slide shows the machine side of a Control Remoting Module. In operation, one of three solenoids is energized to pick the correct operator while the drive motor goes through one revolution. The three operators are mounted on a carrier that is cam operated from the drive motor moving in a vertical plane. Using the motor to power the key actuation treats the machine more gently as well as allowing use of very small solenoids. Since the solenoid is already in contact with the bottom of the operator when it is energized, it requires only about one one-thousandth of the energy to exert a given pull as would be required if the solenoid itself were to power the key actuation.

The last slide shows a small cue tone generator that we have developed for the convenience of both T-MATIC users and duplicating centers. Several of these units have already been distributed to duplicating centers. We expect that all centers equipped to produce Sony U-Matic dups will be equipped with these generators within the next few weeks.

Some of the applications of the T-MATIC system for CATV are:

> As a free-standing program source to program a separate channel on the system, a single T-MATIC console can provide up to five hours of programming while two consoles can provide eight hours of programming. This programming can be continuously repeated for 24-hour-a-day unattended operation.
>
> As a manually accessed program source, the T-MATIC system can provide commercial announcements, feature stories, and news clips to support live studio programming. A small desk top control box permits the talent themselves to access the various T-MATIC machines. A four-second warning light on the same control box tells the announcer of the impending switch back to live camera operation. A strictly one-man news show can thus be a reality.
>
> The T-MATIC system can be used as a source of non-duplication programming by simply routing the audio and video from the station to be protected through the T-MATIC switcher and controlling the switcher from the system's non-duplication programmer.
>
> It can be integrated with film chains or open-reel recorders using the control signals from the automation system to start, pre-roll, and stop the recorders or projectors.
>
> It can be used to program educational channels where the cable system, using their non-duplication programmer and T-MATIC system, can provide automatic pre-programmed unattended origination of educational fare as well as distribution to classrooms throughout the community.

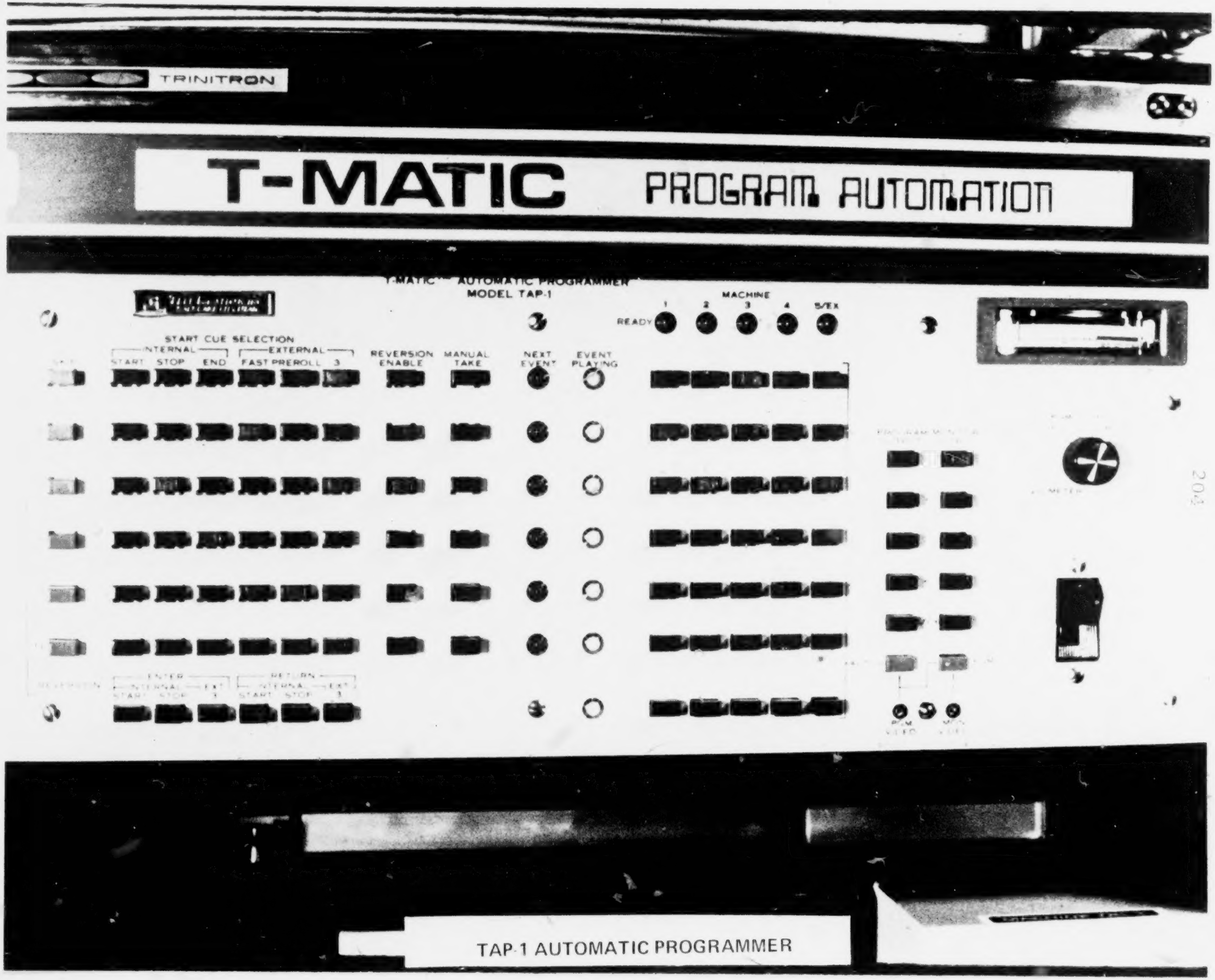
One final thought. The T-MATIC system, although composed of very simple logic elements, is rather complex taken as a whole. What this complexity of circuitry buys us is simplicity of operation to the point that we expect most T-MATIC consoles to be situated in the front offices of cable systems with programming accomplished by office girls.

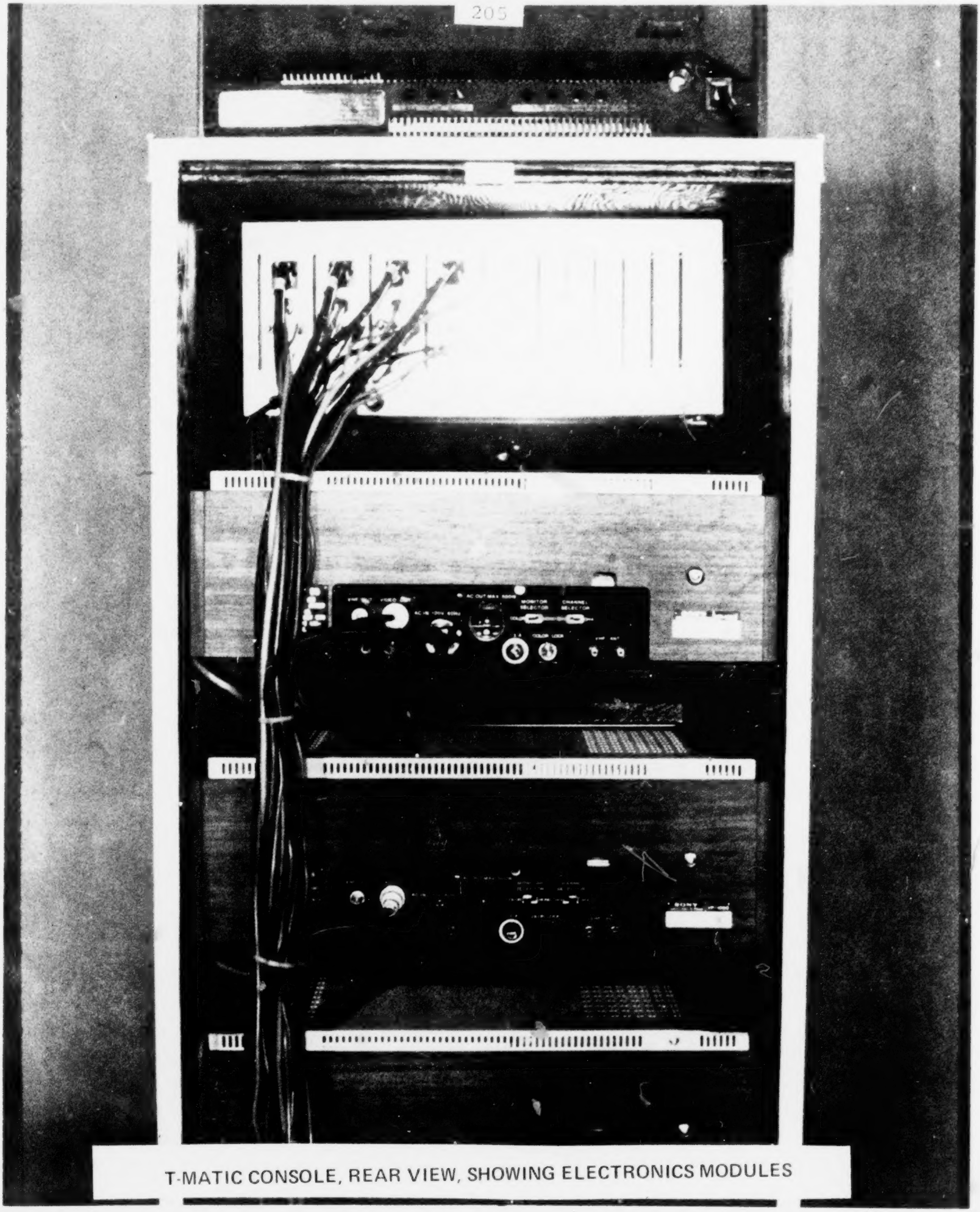
T-MATIC
PROGRAM AUTOMATION

T-MATIC PROGRAM AUTOMATION CONSOLE

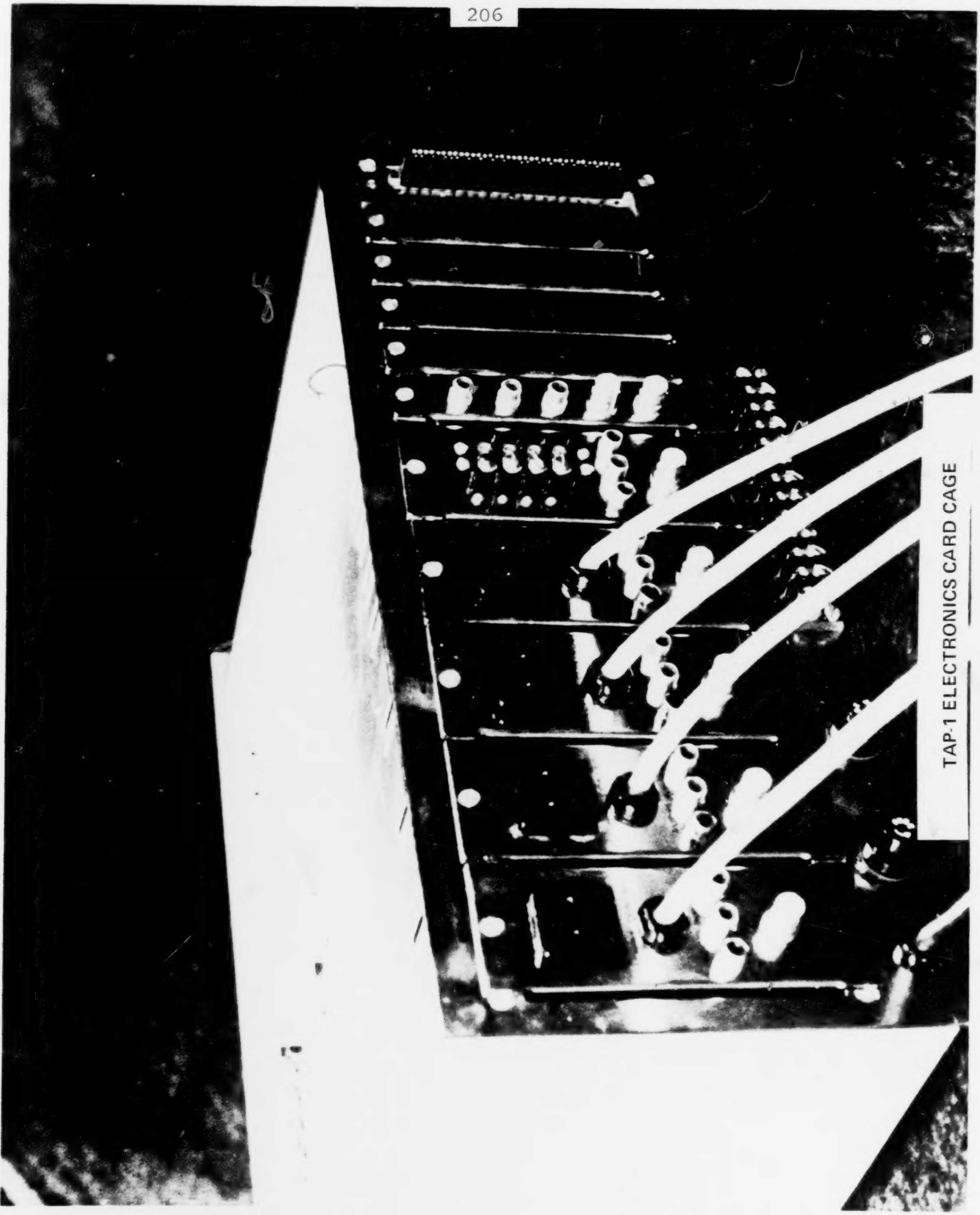
SONY
T-MATIC

T-MATIC CONSOLE SHOWING CONTROL PANEL AND VIDEOCASSETTE PLAYERS

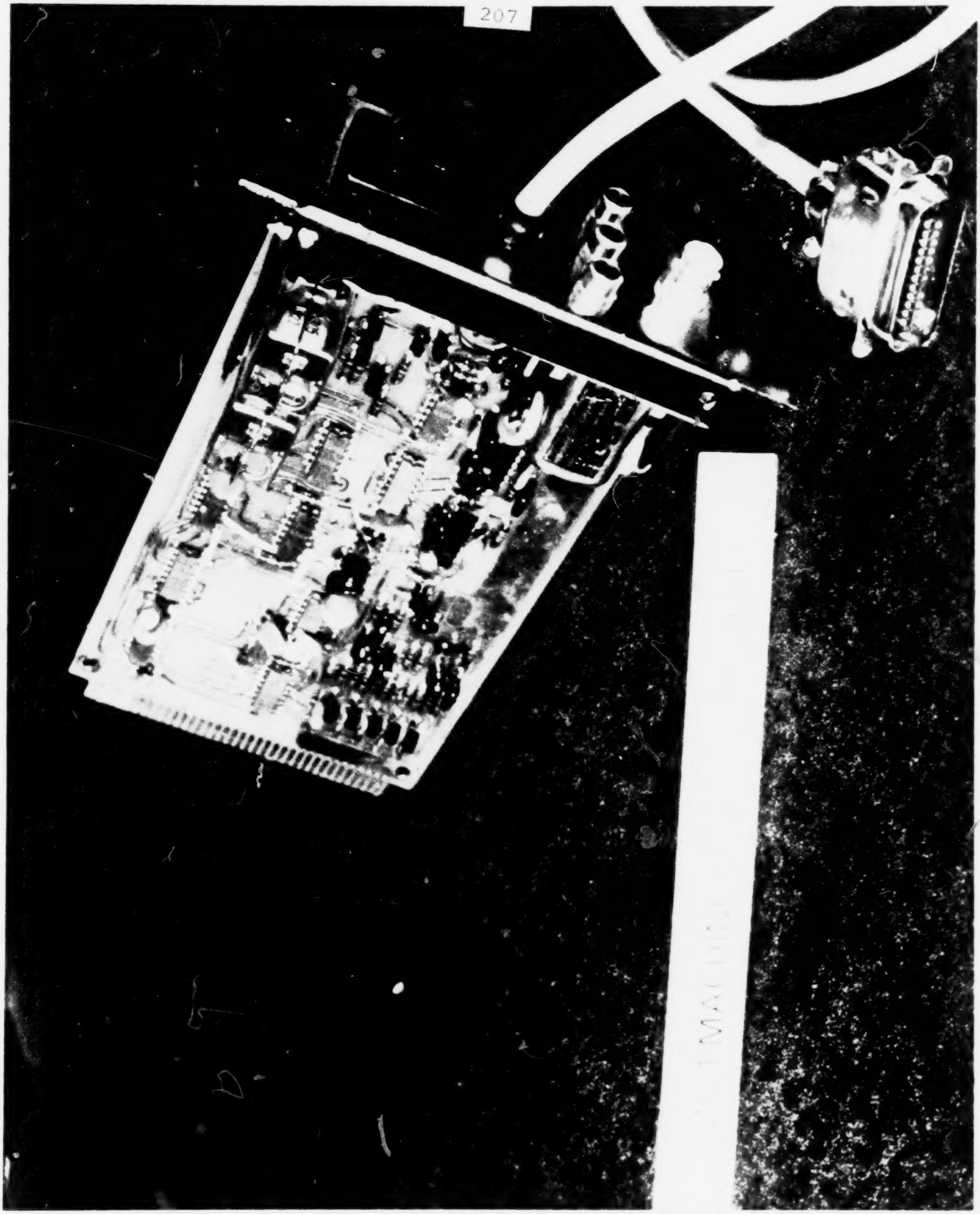

TRINITRON
T-MATIC
PROGRAM AUTOMATION
T-MATIC™ AUTOMATIC PROGRAMMER
MODEL TAP-1
MACHINE
READY
1
2
3
4
S/EX
START CUE SELECTION
INTERNAL
EXTERNAL
START
STOP
END
FAST
PREROLL
3
REVERSION ENABLE
MANUAL TAKE
NEXT EVENT
EVENT PLAYING
REVERSION
ENTER
INTERNAL
START
STOP
EXT 3
RETURN
INTERNAL
START
STOP
EXT 3
PGM VIDEO
MON VIDEO
METER
TAP-1 AUTOMATIC PROGRAMMER


MONITOR SELECTOR
CHANNEL SELECTOR
COLOR LOCK
SONY

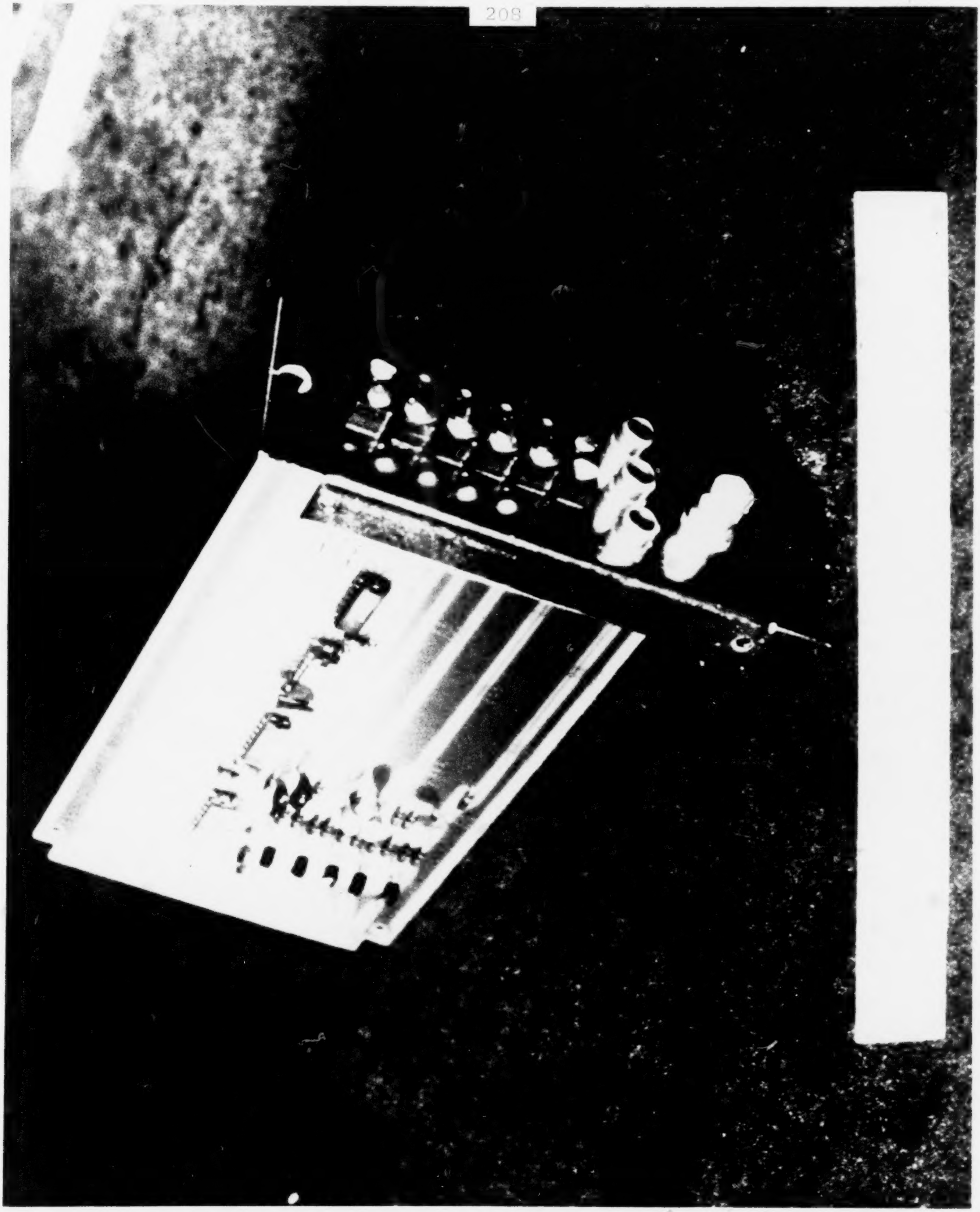
T-MATIC CONSOLE, REAR VIEW, SHOWING ELECTRONICS MODULES

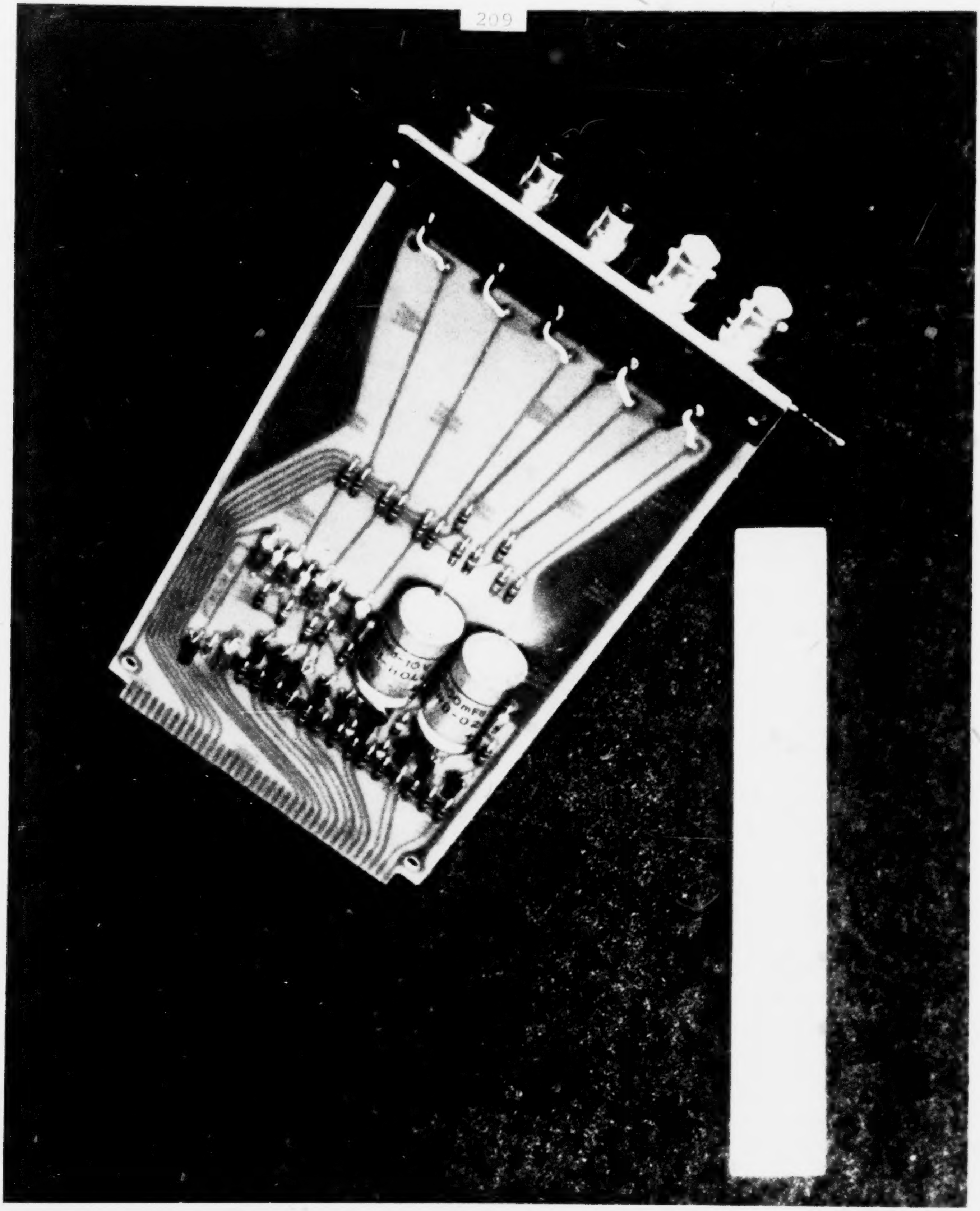


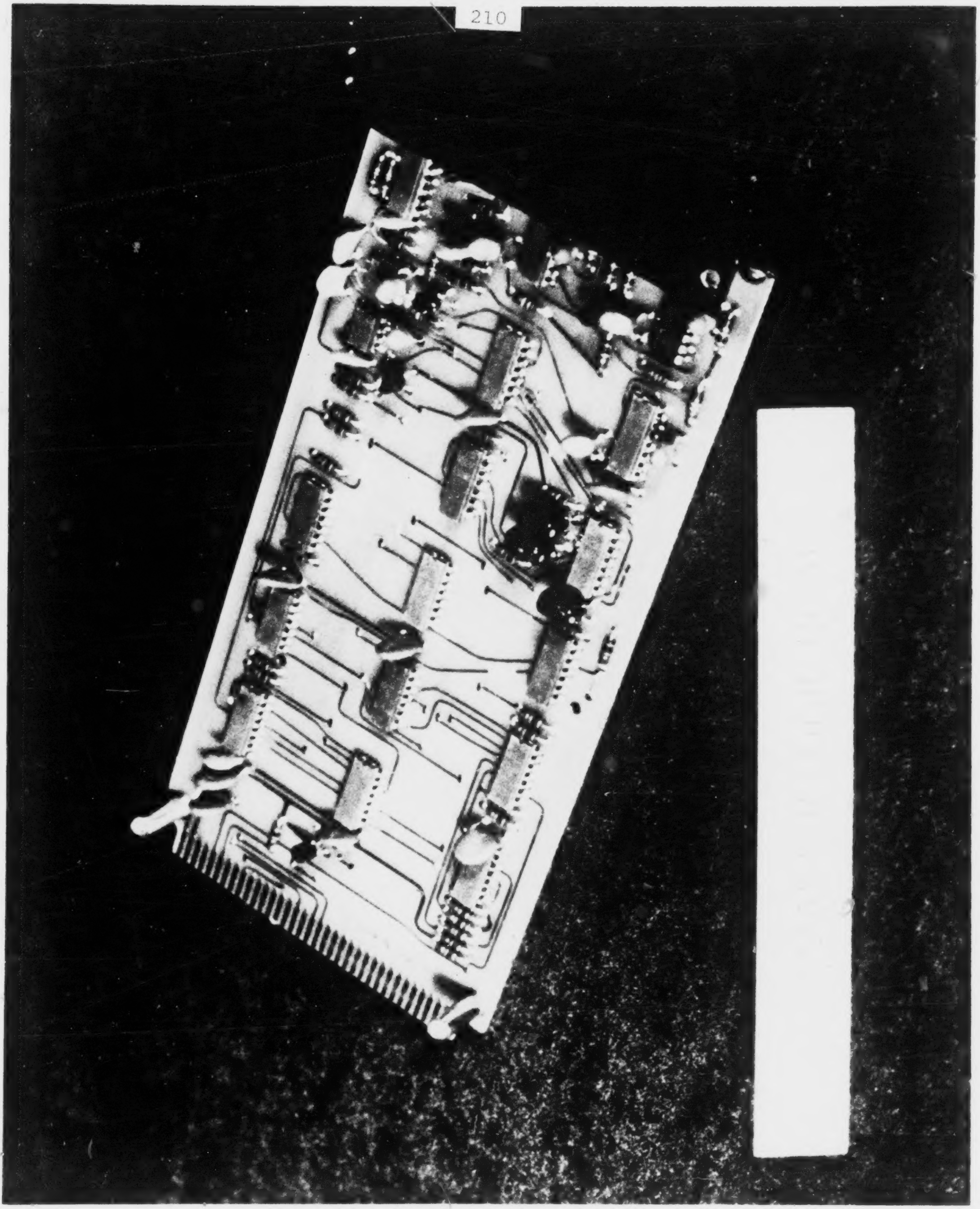
TAP-1 ELECTRONICS CARD CAGE

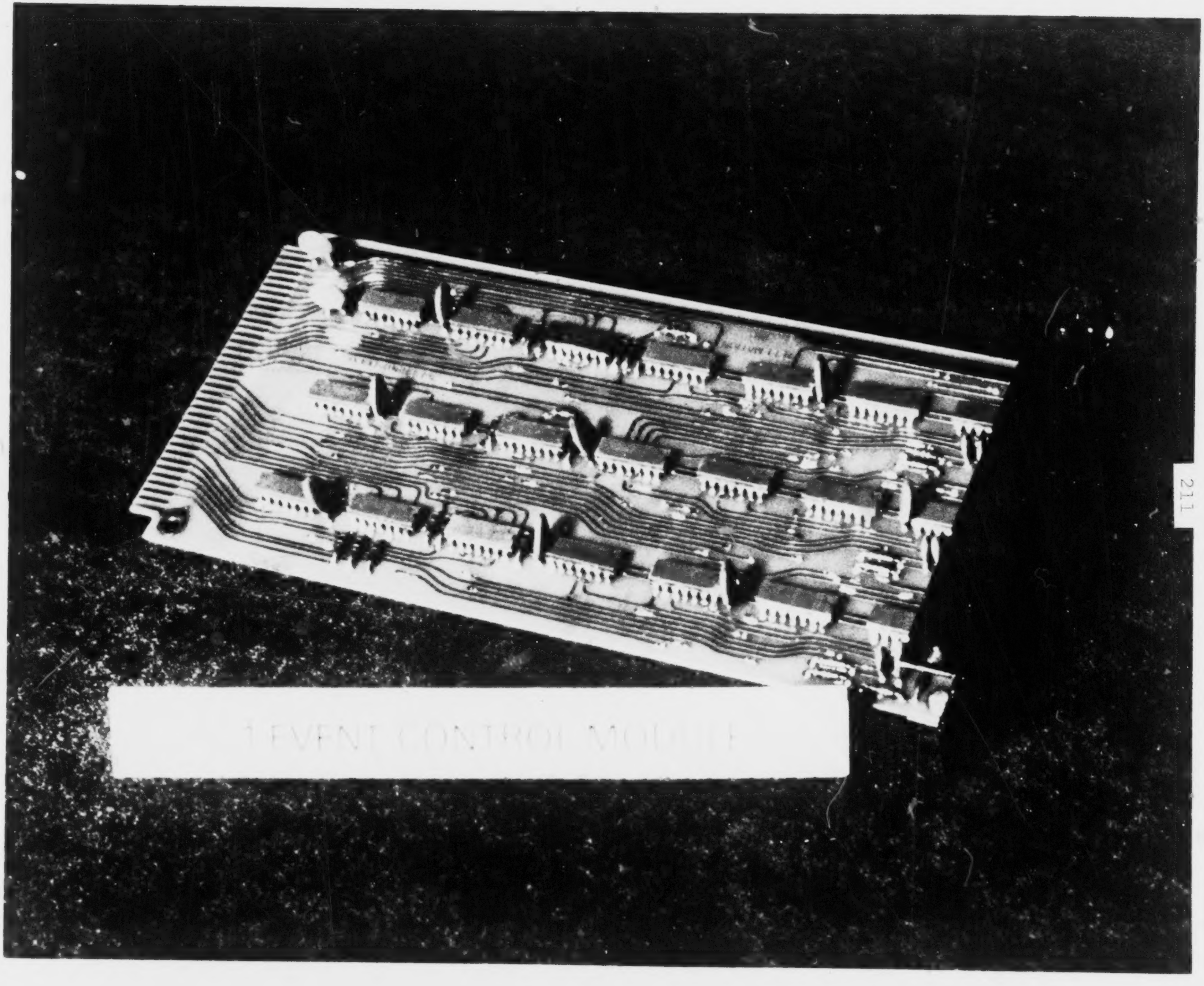


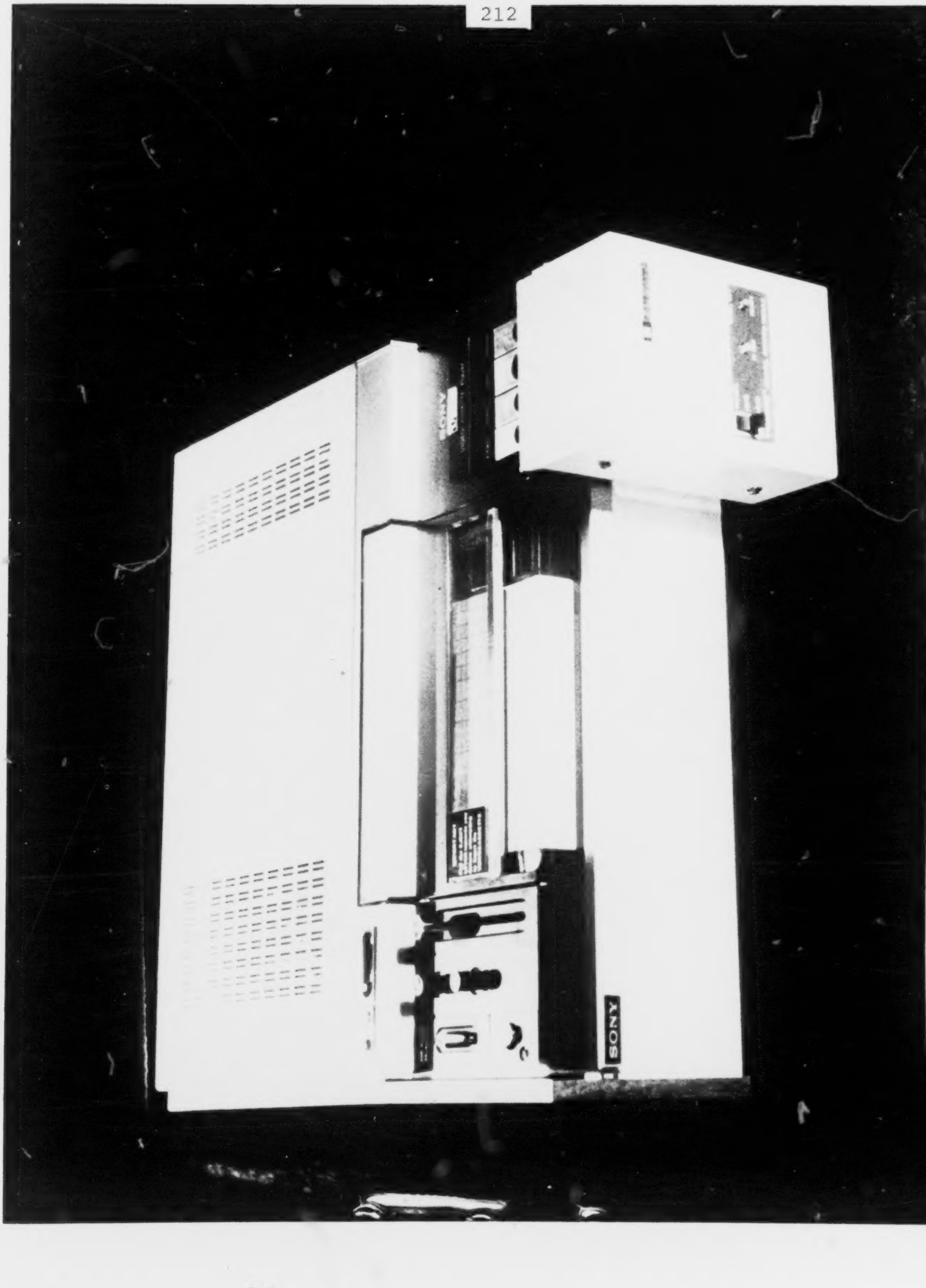
207



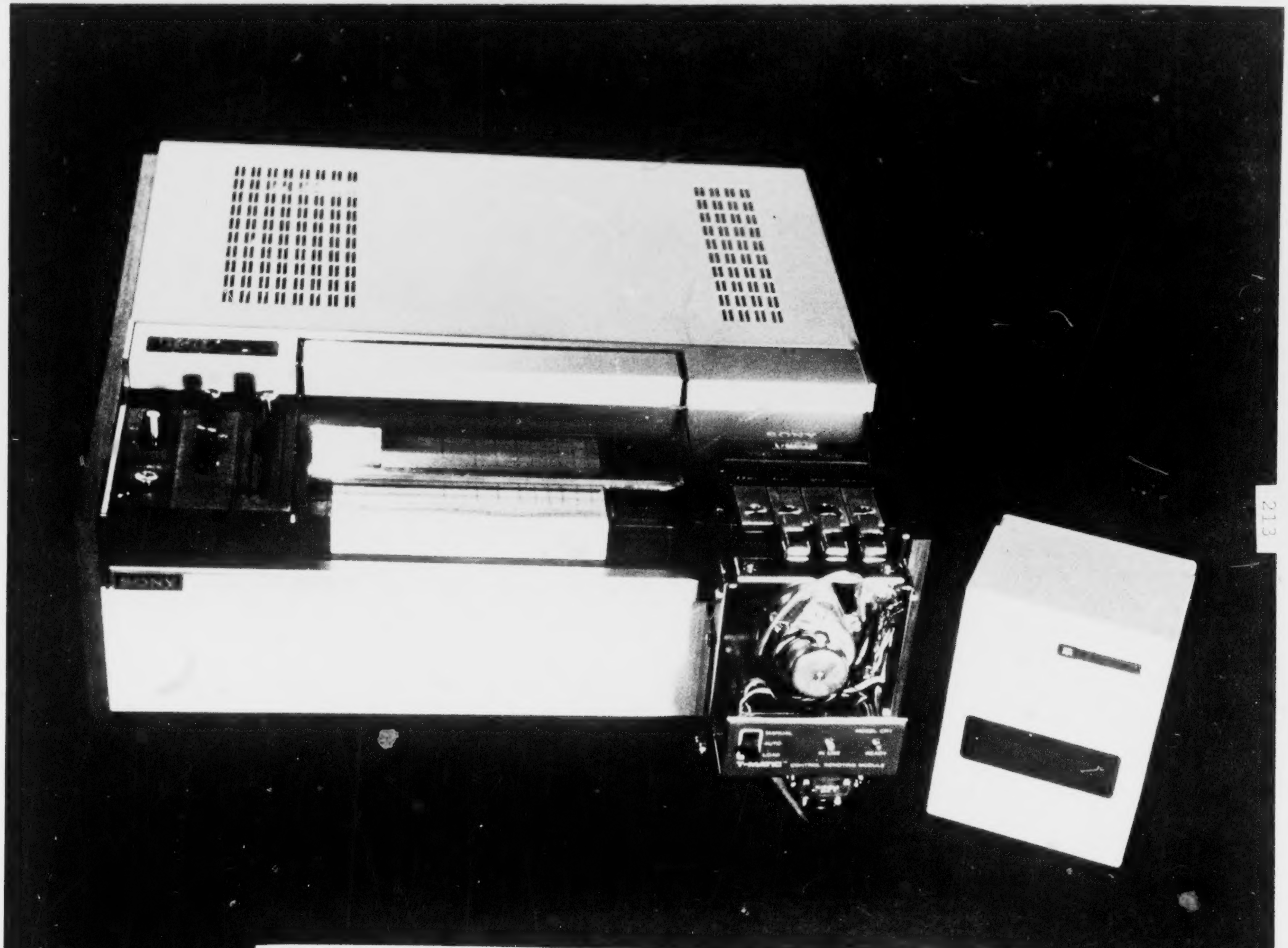




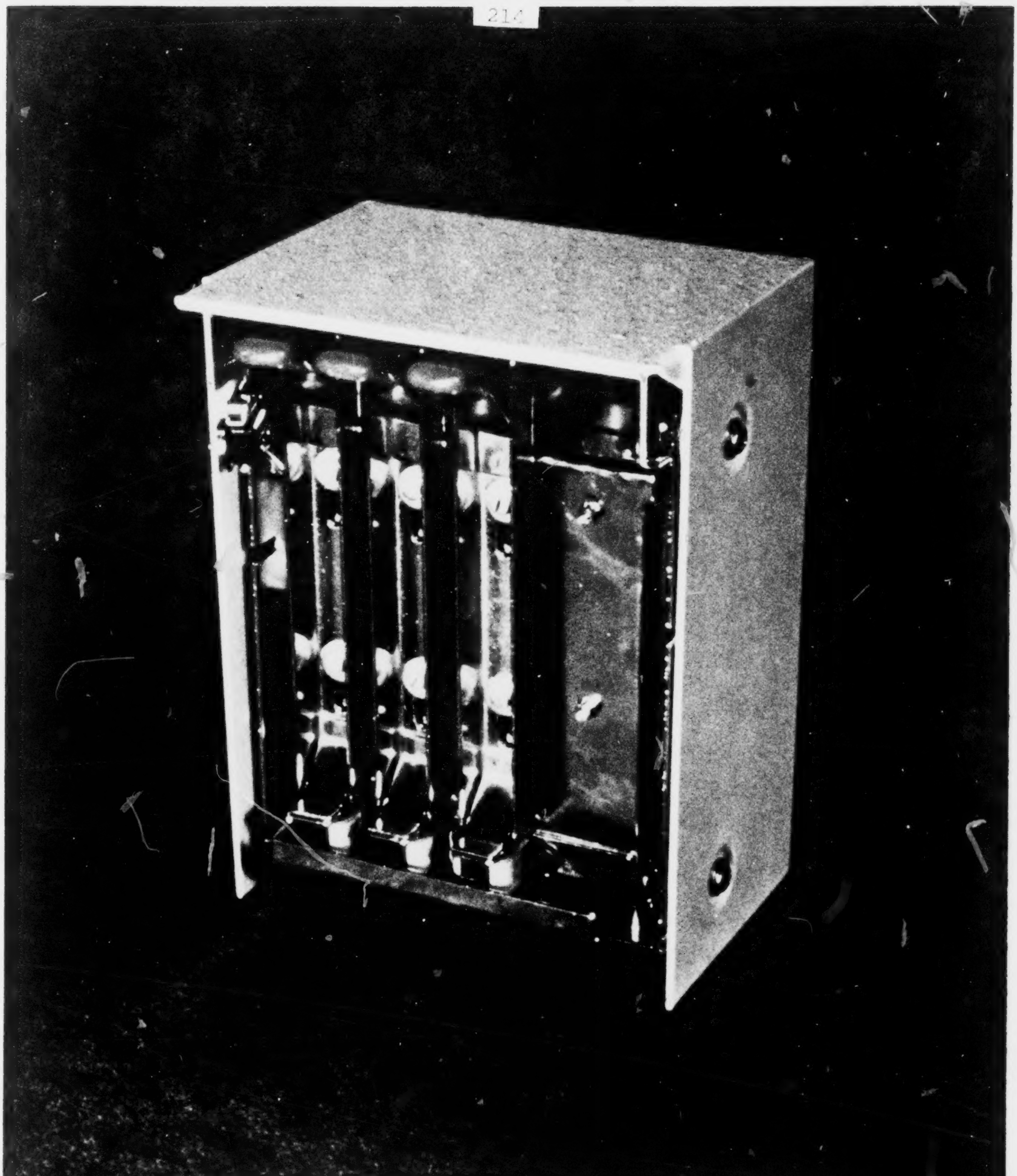

1 EVENT CONTROL MODULE



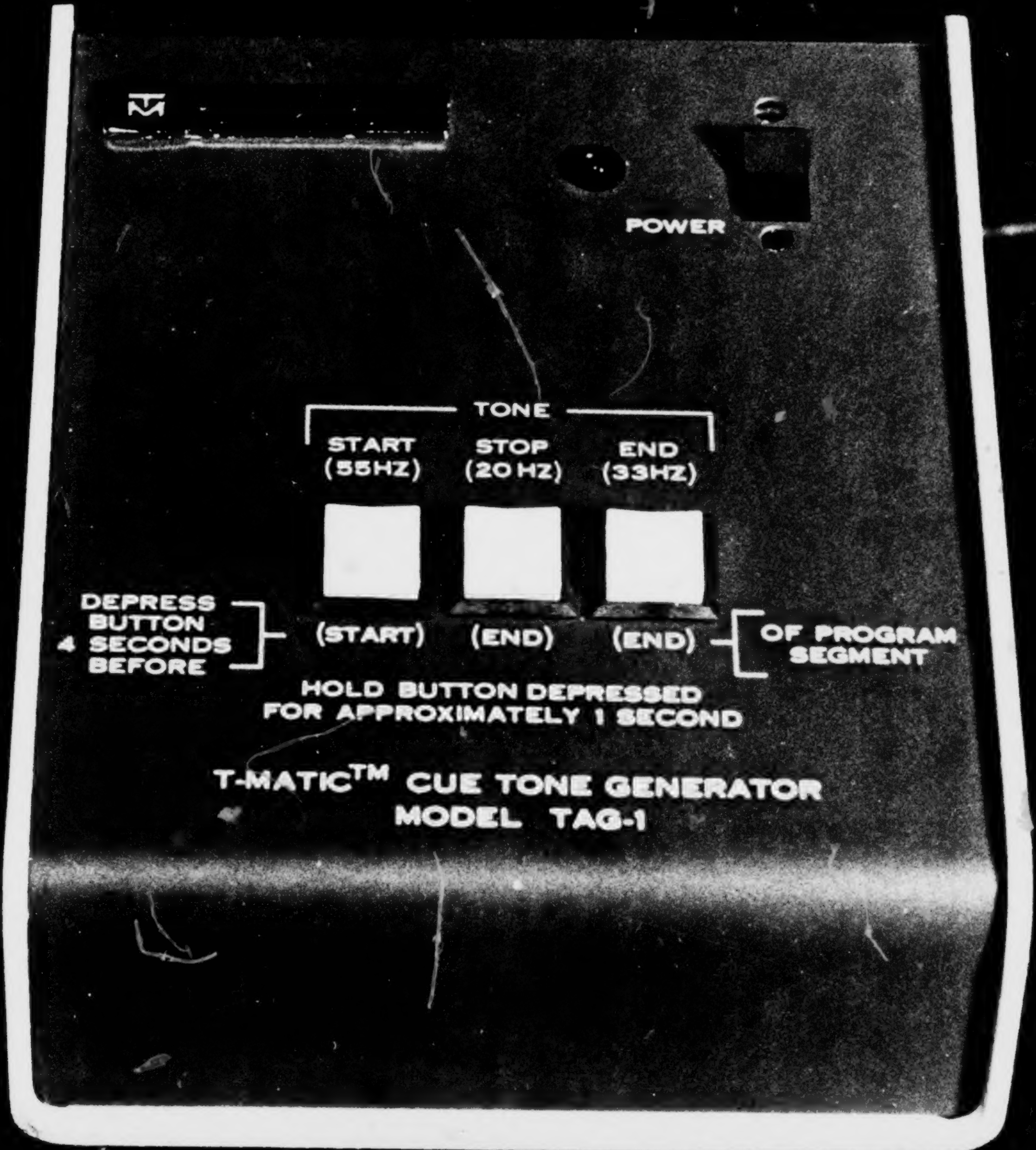
SONY VP-1000 PLAYER WITH T-MATIC CONTROL REMOTING MODULE MOUNTED



MOUNTED CONTROL REMOTING MODULE WITH COVER REMOVED



CONTROL REMOTING MODULE SHOWING KEY OPERATORS


POWER
TONE
START (55HZ)
STOP (20 HZ)
END (33HZ)
DEPRESS BUTTON 4 SECONDS BEFORE
(START)
(END)
(END)
OF PROGRAM SEGMENT
HOLD BUTTON DEPRESSED FOR APPROXIMATELY 1 SECOND
T-MATIC™ CUE TONE GENERATOR
MODEL TAG-1

T-MATIC CUE TONE GENERATOR

DISCABLE

A NEW AUTOMATIC SOUND AND VIEW PROGRAMMING FOR CATV

A paper presented at the 21st Annual NCTA
National Convention, Chicago, May 16, 1972

Co-Authored by
John L. Humphreys - Robert E. Weiblen,
DISCABLE/NATIONAL TREND-IN CORPORATION
1860 Michael Faraday Dr., Reston, Va.

DISCABLE is a new concept in cable services combining FM stereo programming and video display for CATV systems. DISCABLE is a combination hardware-software package that places up to fifty channels of highly tailored musical and radio programming on the FM portion of the cablecasting band. In addition, DISCABLE presents a video printout of the FM programs on useable cable TV channels, while providing the insertion of local video information messages. The DISCABLE system is automatic in operation and is controlled by long play, pre-recorded tape operation, produced by a central production agency.

With the new growth scheduled in the top one hundred markets, cablecasters are faced with limited income revenues from the FM broadcast band. (88 to 108 MHz.) Duplication or re-broadcasting of "over the air" FM stations may provide little incentive for home listeners to subscribe to cable FM because of the abundance of Grade A FM signals. Therefore, local origination of new, non-competitive radio and music services will prove necessary.

DISCABLE can supply an alternate program service through a unique long play tape system. The tape format will be one-half inch wide, employing eight-quarter tracks, running bi-directional at the speed of 7.5ips. This provides TWO STEREO PROGRAM SERVICES per reel. Two reel sizes will be used, 14 inch and 10.5 inch. The long play reels will use one mil, mylar base tape, supplying six hours total running time per 14 inch reel at the normal speed of 7.5ips. Lower quality programming may run at 3.75ips, supplying up to twelve hours of program time per reel.

Special 14 inch tape decks are used to play back the program tapes. These decks are horizontally mounted in a standard rack, and pull out on tray slides for loading. Concentric reel hubbing is used for space consideration on the supply and take-up reels. Therefore, the decks mount one over the other, like file drawers, providing maximum deck space in the minimum of rack and floor space. Up to six decks may be housed in one rack. The additional rack space holds the associated electronic hardware and monitors.

Each equipment package, called a "SOUND ISLAND," provides up to thirty-six hours of uninterrupted and unmanned stereo programs for TWO separate FM radio channels. FM stereo modulation generators are included in each Sound Island. Automatic tape cueing and switching is employed, as well as the use of the Dolby-B noise reduction system. All equipment access will be from the front of the Sound Islands, allowing the cabinets to be placed back-to-back or against building walls. Additional Sound Islands may be added for future channel expansion.

DISCABLE is proposing to divide the fifty FM channels into three basic groups for programming. Group one will be devoted to the promotion of the Recording Industry. Group two will be reserved for "Public Affairs." (i.e. Public Service, Government, Educational and Institutional programming.) And the third group of FM channels will be reserved for "high entertainment radio show." (i.e. pay-radio, syndicated programming, special services.)

Of special interest to CATV operators is the tie-in of digital display printout on adjoining television channels of the publication of the program guides of the various FM radio channels. This information is taken directly from the program tapes and remains in perfect syncronization with the program material. This readout will be displayed for thirty seconds on the television set and the sound of this particular radio channel will modulate the TV aural channel. Then the TV display and sound will switch to the next FM radio channel to be monitored. As more Sound Islands are employed, or the more FM channels broadcast, several additional TV channels may be used for the program guide printout. (i.e. one TV channel for each of the three basic FM programming groups.) Local advertising or message data may be inserted by the cablecaster for display on the TV channels, using the built-in splitscreen technique. This display will be seen below the program guide information as shown in Figure 1. Color keying will be used to separate the readout.

Exposure and promotion of the products of the recording industry is a natural source for part of the DISCABLE programming. The following technical information of DISCABLE is discussed with that format in mind.

Technical Discussion:

The overall operation of the DISCABLE system is explained with reference to Figure 2 in which is shown the arrangement of components as the head-end of the CATV facility. Stereo tapes prepared with Dolby-B processing are played on auto-reversing playback-only machines. Tapes are 7,200 feet long; running at 7.5ips, they offer 6 hours of programming when run through in both directions.

Each selection on the tape is preceded by digital data relating to the name, recording group or artis, composer, record label and catalog number for the selection about to be heard. This digital information is called a selection "header." The header also contains information about one or more following pieces. The header information is recorded as a series and parallel combination of tones so that the digital format will be compatible with audio playback machines. Selection of tones and their duration are such that it is unlikely that they will be inadvertently duplicated in the program material and thereby create confusion of header and audio in the decoder.

Each line of video program guide that will be developed from the header is stored in a separate integrated-circuit memory, as shown in Figure 2. The line memories are each 6x32 or 6x40 bits in capacity, permitting either 32 or 40 characters of data per raster character line from the half-ASCII set of 64 possible alphanumeric and special characters. The use of individual line memories allows flexibility of presentation--for instance, scrolling of portions of the display and steady presentation of other lines. There is a set of line memories for each stereo channel. The program guide printout in each set is sequentially shown on a TV channel. The guide information is presented on the top or bottom half of the raster, with the remaining half available for local advertising. Different colors for the two halves set off the two sets of material. The audio material cablecast over each FM channel is sampled and used as audio background for the video guide when the associated program information is being shown. All timing for sequential presentation of material and scrolling and advertising changes is conveniently obtained from the vertical synch for the video channel.

Video quide information is gathered from the tape into 6-bit character groups and stored in the various line memories. Lines containing fewer than the maximum number of characters are filled with ASCII spaces or blanks to avoid recirculation and display of old data. After the information has been read from the tape and stored, the end of the digital header is sensed and control of the memory is given over to the recirculation and readout control. Characters are generated in dot-matrix form from their 6-bit ASCII equivalents. The 6-bit data are recycled through the line memory to permit as many video presentations as will be required for the duration of the program selection being reproduced from the tape at the moment. Line memory readout is controlled sequentially in accordance with raster vertical position. If there are more line memories than lines presented in the video program guide format, the line memories can be selected in sliding groups such as 1, 2, 3, 4, then 2, 3, 4, 5, then 3, 4, 5, 6, and so forth to effect a scrolled guide. Other line memories filled from a source other than the program tape (such as cassette or paper tape) are also processed in the sequence to fill, say, the bottom portion of the raster to provide advertising space. Advertising is changed or sequenced independently of the program guide information and continues while the program guide memories are being updated and while the program tape is awaiting change or maintenance.

In addition to the headers for each audio selection, there are cueing control tones and a tape reel identifier on the tape. The identifier is a tone-code placed at the beginning of the reel that is sensed after the tape is started. The identifier tones are recorded in a tape cassette for verification and audit purposes. The tone code contains cassette start and stop commands as well as ID information, thus automating the verification procedure. Cueing tones recorded at the beginning and end of the tape set up the tape to the beginning of the recorded material, reverse the direction, and finally stop the tape after the reverse-direction tracks have been played and the tape is wound back onto its original reel.

Tape masters are prepared with the aid of a mini-computer, as shown in Figure 3. The mini both directs the sequence of selections to be recorded and generates the digital tone codes for the selection headers. After a three- or six-hour program has been decided upon and details have been laid out, two lists of the selections are drawn up. One list contains details concerning each selection as mentioned earlier; the entries in this list will appear in the two "now playing" character lines of the video presentation. The other list is comprised of less detailed information about each selection and each such entry will occupy one video character line in the "next to be heard" list. The lists are typed on a keyboard entry device for the mini and stored in its memory, subject to verification and correction of list data. A four thousand world memory is sufficient.

When the tape is first created, the computer types out the name of the first selection. This ensures that the selections are recorded in the intended sequence. The computer is then commanded to generate the tone code sequence for the detailed list entry associated with the upcoming selection, and for several entries in the less detailed list for the next several selections. The computer indicates when the header has been completed (several seconds) and the computer pauses while the selection is recorded. The operator requests the name of the next selection from the computer and the process is repeated, now with the next entry from the detailed list and the next appropriate grouping of selections subsequent to the selection about to be recorded.

The ASCII-coded data for each alphanumeric character in a list entry are treated in bit-serial fashion. Each bit value controls the states of tone generators encoding data and control functions. The tone sequences thus developed are recorded on the tape and comprise the header that is read by the head-end playback equipment and reconstructed into ASCII characters and stored for video presentation.

Conclusion:

The DISCABLE system, for the first time in radio history, allows the addition of a visual presentation, promoting radio tune-in.

The FM radio channels must not be ignored or discounted, during the fast growth of cable systems. Radio, by itself, is an effective, imaginative, and vital communicator; it should be used and expanded. DISCABLE offers an exciting and valuable service to cablecasters in the dynamic communications explosion by CATV.

Biography of Authors:

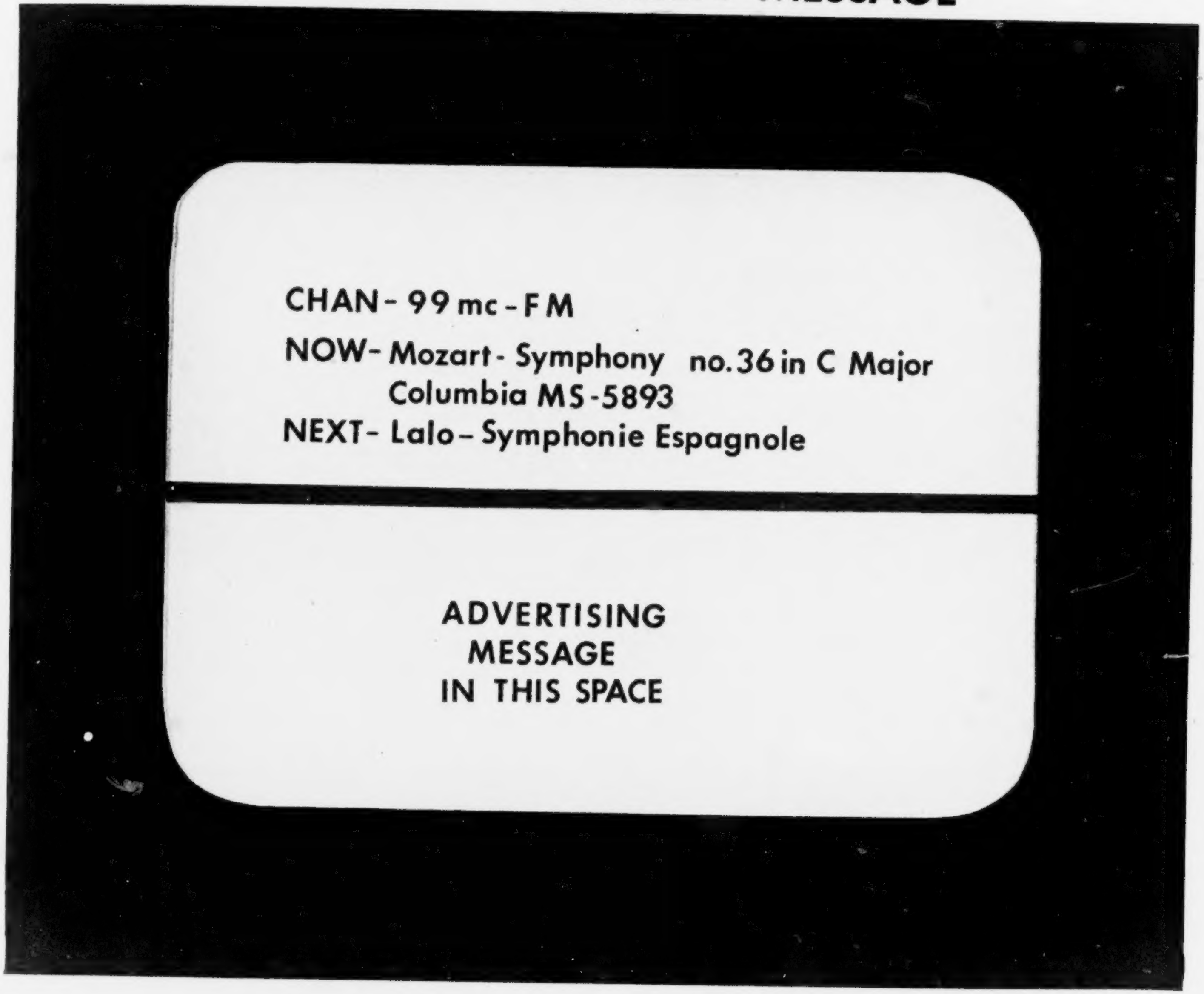
John L. Humphreys - Seventeen years experience in Radio and Television Broadcasting. President of National Trend-In Corporation, Reston, Virginia, serving the CATV and Broadcast Industries with magnetic tape products, high speed tape duplication, program syndication and facility development.

Robert E. Weiblen -

Stevens Institute of Technology -	BS, 1955
Columbia University -	MS, 1962

Seventeen years experience in electronics R&D, product development, marketing and management. President of Household Data Services, Incorporated, a small research and development firm concerned with two-way CATV services and hardware.

TYPICAL TV SCREEN MESSAGE



CHAN- 99 mc - F M

NOW- Mozart - Symphony no. 36 in C Major
Columbia MS-5893

NEXT- Lalo - Symphonie Espagnole

ADVERTISING
MESSAGE
IN THIS SPACE

FIGURE 1

DIGITAL PROCESSING & VIDEO GENERATION

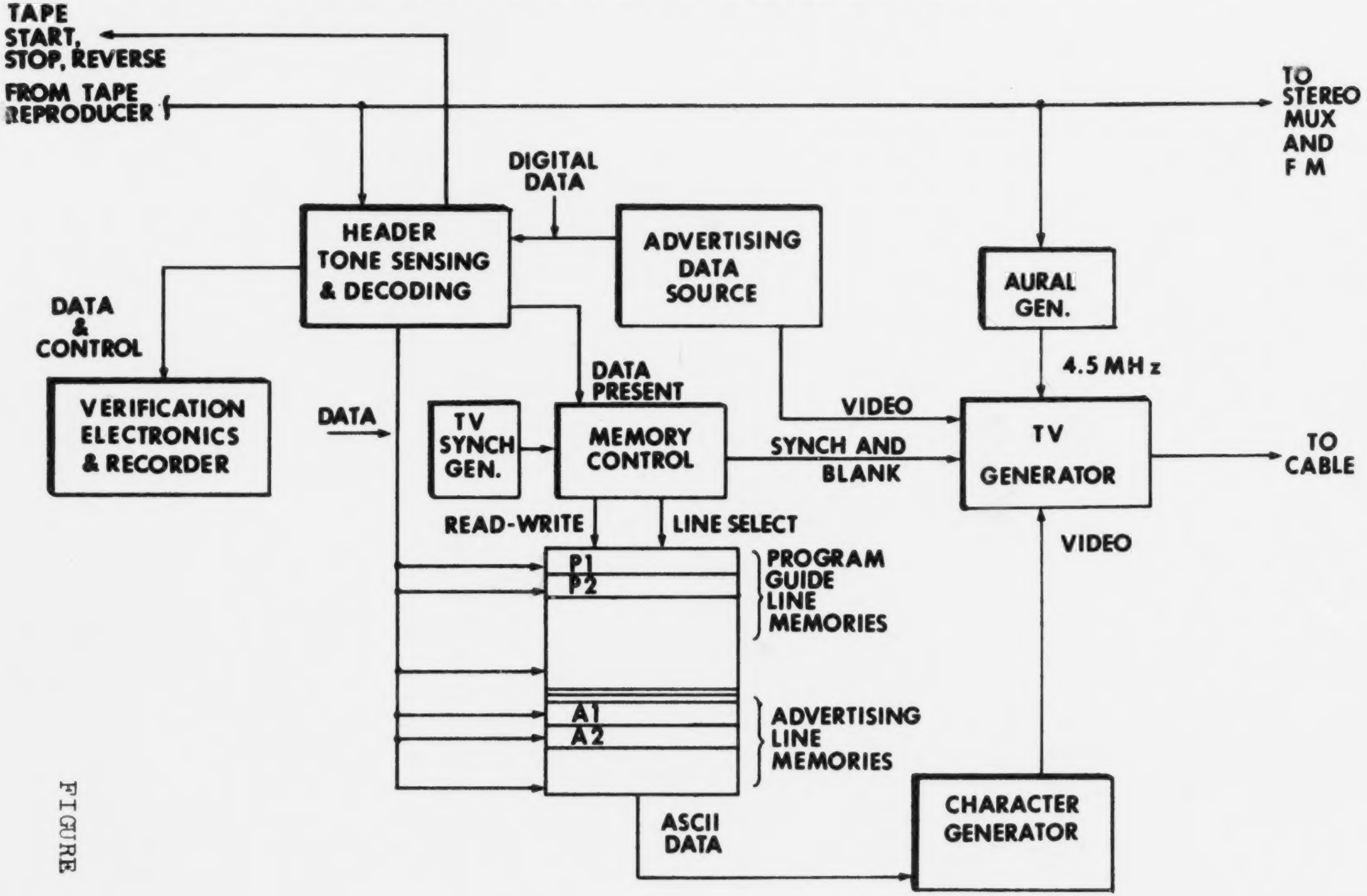
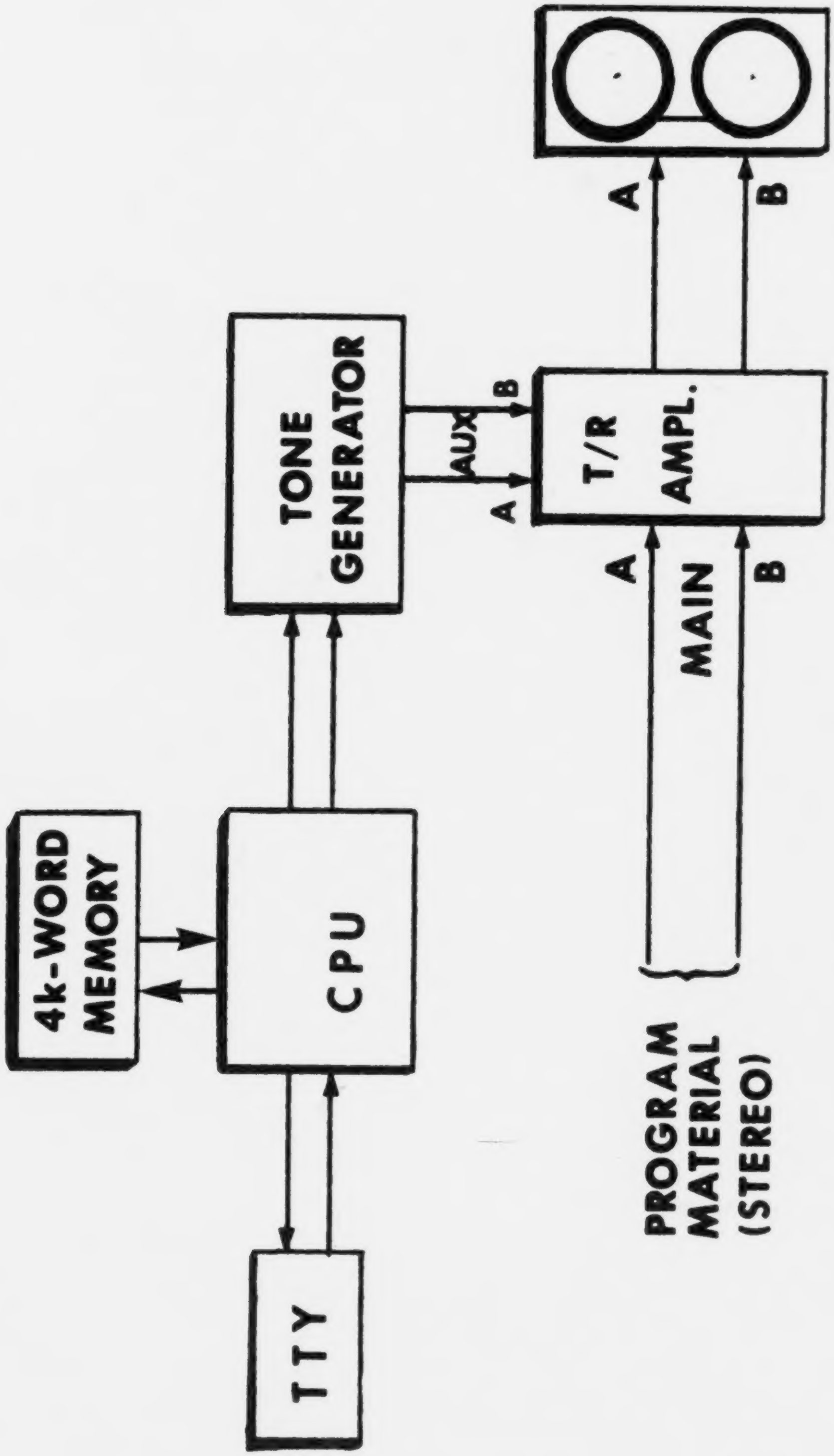

TAPE START, STOP, REVERSE
FROM TAPE REPRODUCER
TO STEREO MUX AND F M
DIGITAL DATA
HEADER TONE SENSING & DECODING
ADVERTISING DATA SOURCE
AURAL GEN.
DATA & CONTROL
VERIFICATION ELECTRONICS & RECORDER
DATA
DATA PRESENT
4.5 MHz
TV SYNCH GEN.
MEMORY CONTROL
VIDEO
SYNCH AND BLANK
TV GENERATOR
TO CABLE
READ-WRITE
LINE SELECT
VIDEO
P1
P2
PROGRAM GUIDE LINE MEMORIES
A1
A2
ADVERTISING LINE MEMORIES
ASCII DATA
CHARACTER GENERATOR

FIGURE 2


TTY
4k-WORD MEMORY
CPU
TONE GENERATOR
AUX
A
B
T/R AMPL.
PROGRAM MATERIAL (STEREO)
MAIN
A
B
A
B

MASTER TAPE PRODUCTION

FIGURE 3

PRIVACY FOR CABLE SERVICES

Frank R. Eldridge
The MITRE Corporation
McLean, Virginia 22101

Abstract

This paper reviews the need for the next generation of urban cable systems to provide various types of private cable services. It reviews current methods of providing Premium TV services, and various types of video channel switching and channel selection systems, as well as the types of address gating systems currently being developed and demonstrated by The MITRE Corporation on the Reston, Virginia, cable system. Finally, it discusses the possibility of developing a composite channel-selection-and-address-gating system that appears to offer an attractive and relatively inexpensive means of providing both private services and Premium TV services in future urban cable systems.

WHY PRIVACY

For many years cable has spread throughout the rural areas by providing improved signals where off-the-air reception is poor. However, saturation of cable systems in these areas is rapidly approaching. New opportunities for viable systems, that supply only off-the-air signals, are becoming harder and harder to find.

In order to reach into cities, where many satisfactory off-the-air signals are already available, cable must supply a number of new and attractive types of services.[1] Many of these potential services will require at least some degree of privacy to be both effective and acceptable to the public. Mail delivery, bank-account information, credit checks, stock portfolio information, and access to personal files, are all examples of services that will require privacy. Security of files of private information stored in central processing units and transmitted to thousands of terminals in homes and offices, served by the cable system, will be needed. Many people will demand not only complete privacy of information transmitted specifically to their terminals but also a right to view any channels without information being gathered on which channels they are tuned into at any particular time.

What means are available, then, to designers and operators of these new types of cable services, that will guarantee these types of privacy?

The literature contains many articles that present possible ways of maintaining security of private files stored in central computer memory banks.[2] These include special computer programs that store private information in a number of preselected sections of a memory bank, and the use of unique codes or passwords to gain access to these private sections of a memory bank.

There has also been a great deal of discussion on how user privacy in viewing of open channels should and could be maintained.[3]

However, the problem of how to maintain the security of private information transmitted to terminals in homes and offices throughout a cabled city has received relatively little attention. This is the problem that is focused upon here.

CHANNELS AND SERVICES

A categorization of the types of cable channels that will be involved in these types of cable systems is shown in Figure 1. It is expected that most cable systems will eventually carry both downstream channels from headends to the system terminals, and upstream channels from the terminals to the headends. The downstream channels can be classified as follows:

- Subscription channels – That is, channels provided to subscribers for a monthly fee, and which carry open services, available to everyone as in conventional CATV, as well as private services, available only to designated individual terminals.
- Exclusive channels – That is, channels that are provided to subscribers and other users of the system for an extra fee. These channels will carry Premium TV, and utility services, such as meter reading, or selective power control, as well as various types of maintenance services, etc.

In general, urban cable systems can be expected to carry both one-way and two-way services on the subscription channels. The one-way services will be provided on downstream channels carrying conventional video signals at 60 fields per second and will be received on standard TV sets.

Several types of two-way systems are being developed for use in future cable operations.[4] These will carry both conventional and time-shared video and data signals on downstream channels, as well as time-shared data signals on upstream channels.

The types of services that can be provided by one-way and two-way systems are shown in Table 1. The one-way subscription services will include local and imported off-the-air signals, mechanical signals, local programming, new movies, local sports events and other programs that will normally be carried on the open-service channels and can be tuned-in by any subscriber. In general, it is expected that private services will not be provided on conventional one-way systems, but rather on two-way, using time-sharing and address-gating techniques, as discussed later. Such modes will enable available channel space to be used more effectively.

As indicated in Table 1, the two-way system could carry a variety of services such as polling services, computer-aided instructions, slide lectures, social services, video library shopping and reservation services, and a variety of others on time-shared open channels available to all subscribers. On the time-shared private channels they could provide services such as mail delivery, bank account information, credit checks, stock portfolio information, and access to personal files.

Private transmissions using two-way time-shared channels will, in most cases, be originated from private sources, stored and retrieved from private data banks, and addressed to unique terminals in the cable system.

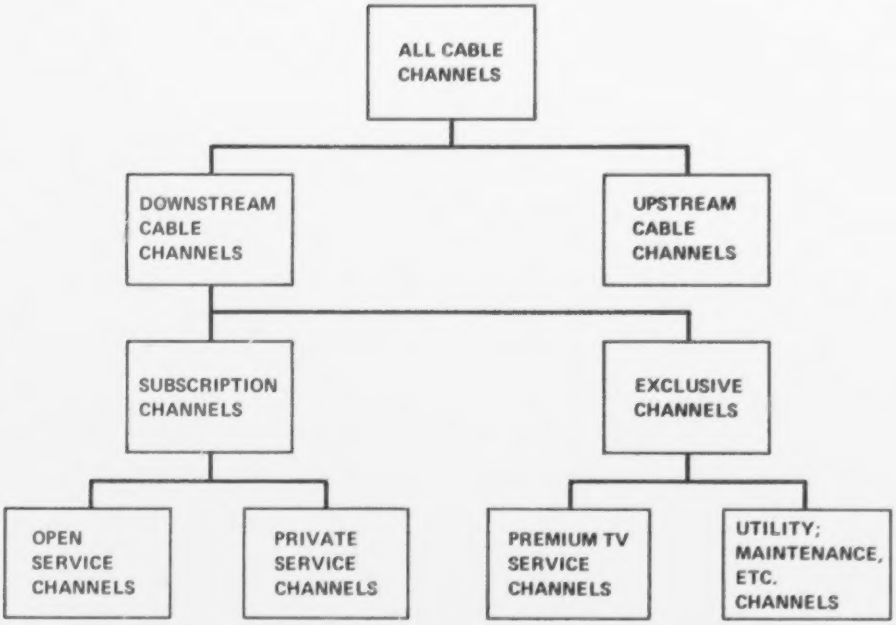

ALL CABLE CHANNELS
DOWNSTREAM CABLE CHANNELS
UPSTREAM CABLE CHANNELS
SUBSCRIPTION CHANNELS
EXCLUSIVE CHANNELS
OPEN SERVICE CHANNELS
PRIVATE SERVICE CHANNELS
PREMIUM TV SERVICE CHANNELS
UTILITY; MAINTENANCE, ETC. CHANNELS

FIGURE 1
CLASSIFICATION OF CABLE CHANNELS

TABLE 1
TYPES OF SUBSCRIPTION SERVICES PROVIDED

	ONE-WAY SYSTEMS	TWO-WAY SYSTEMS
OPEN CHANNELS	• LOCAL SIGNALS • MECHANICAL SIGNALS • IMPORTED SIGNALS • LOCAL PROGRAMMING • NEW MOVIES • LOCAL SPORTS EVENTS • ETC.	• POLLING SERVICES • COMPUTER-AIDED INSTRUCTION • SLIDE LECTURES • HOME COMPUTER • SOCIAL SERVICES • VIDEO LIBRARY • SHOPPING SERVICES • RESERVATION SERVICES • ETC.
PRIVATE CHANNELS	NONE	• MAIL DELIVERY • BANK ACCOUNT INFORMATION • CREDIT CHECKS • STOCK PORTFOLIO INFO. • ACCESS TO PERSONAL FILES • ETC.

In contrast, Premium TV services, such as first-run movies, special national sports events, and various types of special cultural events will, generally, be cablecast on exclusive channels to large audiences.

PREMIUM TV

At present, a number of Premium TV Systems are being developed for use on cable.[5] Many of these are, currently, aimed primarily at hotel and motel applications. Some of these types of systems are summarized in Table 2. Most of the currently available Premium TV systems would use One-Way cable. Many of the systems transmit signals that are scrambled by removal of the sync pulses, or the signals are switched-on at the viewing terminal by a central control-station. None of these currently available Premium TV Systems would be suitable for sending large numbers of short, individual private messages addressed to any of thousands of specific terminals in a large city.

SWITCHING SYSTEMS

One class of systems that should be considered as having the potential for providing privacy of information transmitted via cable, are switching systems, such as those produced by Rediffusion[6] (i.e. The Dial-a-Program System) and Ameco[7] (i.e. the DISCADE System). However, it should be noted that the switching in these systems, as currently designed, is controlled by the viewer rather than the sender. Each viewer, therefore, would have access to all messages on every time-shared private channel to which he had access through the local switching center. A possible means of overcoming this problem would be to supply these switching systems with address gating such as is being done for the MITRE TICCIT System.[8]

ADDRESS GATING

In the TICCIT System each conventional TV field carries an address, in the form of a series of bits inserted before the vertical retrace period that precedes the field. If the address of a frame matches that of an address decoder that is inserted in the system, it passes through a corresponding gating circuit and is received by the terminal to which it is addressed. A unique address is provided for each terminal. Such a configuration is shown schematically in Figure 2. A device such as this, which is operative in Reston, Virginia, is shown in Figure 3, with the top removed.

One problem in regard to the privacy of the address-gating as presently operated on the MITRE TICCIT System in Reston is that all messages carried by each channel are sent to each home and could be taped and read by every user of the system. Such an important objective, here, is to maintain security for all private messages on these channels, each subscriber's address decoder and gating circuit should be located outside of his home and preferably in a local distribution center such as the strand-mounted Area Distribution Center, in the case of the DISCADE System, or in the Program Exchange Center, in the case of the Dial-a-Program System. This will prevent each subscriber from having access in his home to everybody's private messages on the time-shared private channel to which he has switched. By locating his address decoder and gating circuit outside of his home, only those private messages addressed to him will reach his home.

TABLE 2
SUMMARY OF PREMIUM TV SYSTEM DEVELOPMENTS

NAME OF SYSTEM	TYPE OF CABLE SYSTEM REQUIRED	METHOD OF EXCLUDING NON-PAYING VIEWERS	METHOD OF ACCOUNTING FOR SERVICE CHARGES	ESTIMATED INCREMENTAL CAPITAL COSTS
BTVision	One-Way	Video sync pulse and audio signal sent on separate channels, and recombined with video signal at receiver	Identification code for each program recorded on audio cassette and returned, periodically, by mail	$100 per Terminal
EnDeCODE	One-Way	Similar to BTVision	Fixed rate for service	$40 per Terminal
Computer Television	Two-Way	Viewer transmits program requests to central control station via cable. Central control remotely sets varactor tuners in subscriber terminals	Central control records programs requested	$600 per Terminal
K'Son	One-Way	Viewer telephones requests to central control station. Central control remotely sets program selector units to desired channel	Central control records programs requested	$100 per Terminal
Optical Systems	One-Way	Encoded signals sent from headend which are decoded at receiver by use of decoder cards or plug-in decoder cartridges	Viewer buys decoder cards or plug-in decoder cartridges for series of programs	$35 per Terminal
Phonevision and Theatre VisioN	One-Way	Encoded signals sent from headend which are decoded at receiver by subscriber ticket and decoder control unit	Viewer buys decoder tickets for individual programs	Not specified

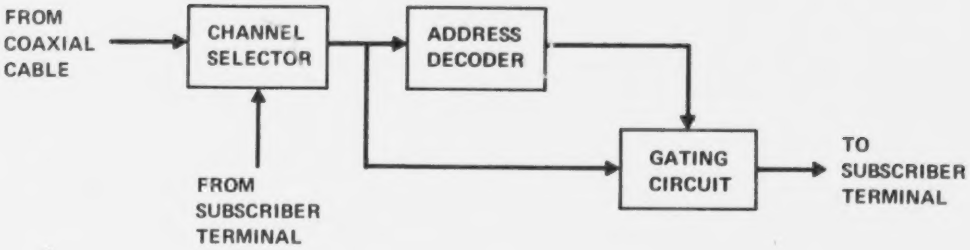

FROM
COAXIAL
CABLE
CHANNEL
SELECTOR
ADDRESS
DECODER
GATING
CIRCUIT
TO
SUBSCRIBER
TERMINAL
FROM
SUBSCRIBER
TERMINAL

FIGURE 2
SYSTEM FOR CHANNEL SELECTION AND ADDRESS GATING

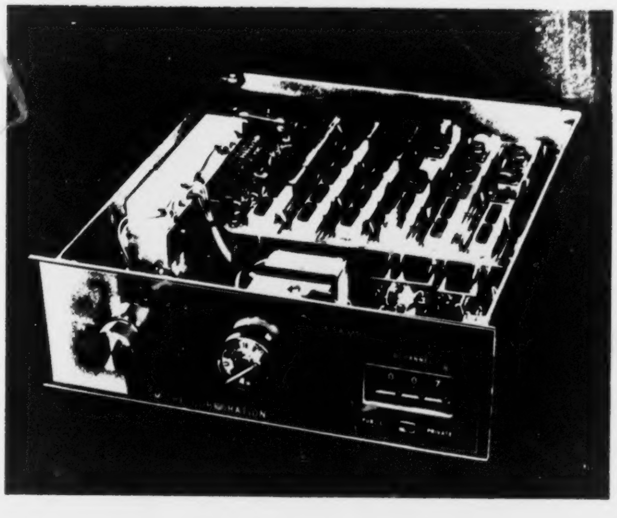


FIGURE 3
MITRE ADDRESS GATING SYSTEM

VARIATIONS

There are many possible variations on this type of privacy system. For instance, an alternative would be to eliminate the use of a local distribution center and, instead, to locate the channel selector, address decoder and gating circuits, shown in Figure 2, in an external unit at the input end of the subscriber's dropline, either on a utility pole or in an underground conduit, and to provide for remote tuning of the channel selector from the subscriber's terminal.

In still another version, a Premium TV mode could be added to the system. Each Premium TV field would carry a "price-per-frame" code as well as a Premium TV address code. Each subscriber's external unit, in addition to the subscriber's unique address decoder, would contain a Premium TV channel address decoder which would be the same for all Premium TV subscribers. When the subscriber tunes into a Premium TV channel, these fields would pass through the Premium TV gating circuit as shown in Figure 4, and the count of the "price-per-frame" code would be registered in the Subscriber-Response Unit, the details of which are shown in Figure 5. The Premium TV field would then pass to the home terminal unit. The price information would be sent to a central processing unit for billing purposes.

Likewise a private mode field, bearing the subscriber's address, would be passed to the subscriber's terminal unit and through a refresh unit if frame-stopping is required.

Open channel signals would be passed directly to the home terminal unit from the remote channel selector and converter.

A keyboard would be supplied in the home terminal unit for generation of upstream signals through the Subscriber-Response Unit for functions such as opinion polling, catalogue shopping and reservation services. This unit could also be used for meter reading, selective power control, maintenance checking, burglar alarms, fire alarms and other sensor interrogation services.[9]

COSTS

Recent studies[1] have indicated a comprehensive two-way terminal of the type described above, in production quantities, would cost anywhere from $327 to $627 without privacy or Premium TV modes. It is estimated that the cost of extra components needed for these modes and packaging and weatherproofing of the components that would be located in the external unit, would add about 10% to these costs.

SUMMARY

In summary, it appears that an attractive and relatively inexpensive means of providing both private communications and Premium TV services to homes, and other potential subscribers, would be to include an external unit, located either in a local distribution center or mounted on a pole or in an underground conduit at the input to the subscriber's dropline. This external unit would contain a means for remote channel-selection by the subscriber, as well as address-gating and subscriber-response units.

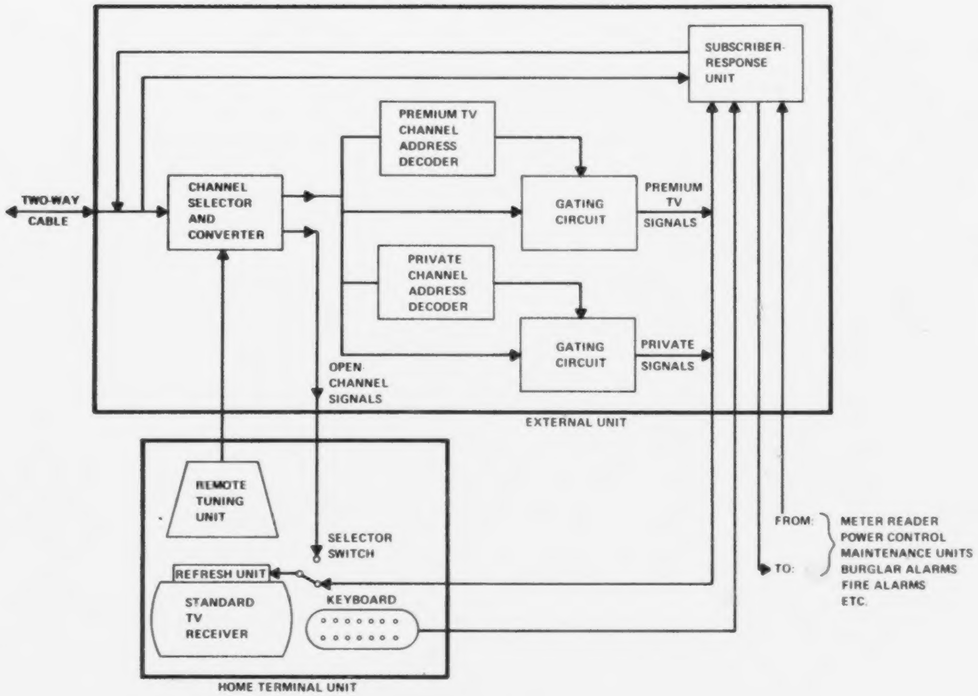

SUBSCRIBER-RESPONSE UNIT
PREMIUM TV CHANNEL ADDRESS DECODER
TWO-WAY CABLE
CHANNEL SELECTOR AND CONVERTER
GATING CIRCUIT
PREMIUM TV SIGNALS
PRIVATE CHANNEL ADDRESS DECODER
GATING CIRCUIT
PRIVATE SIGNALS
OPEN-CHANNEL SIGNALS
EXTERNAL UNIT
REMOTE TUNING UNIT
SELECTOR SWITCH
REFRESH UNIT
STANDARD TV RECEIVER
KEYBOARD
HOME TERMINAL UNIT
FROM:
TO:
METER READER
POWER CONTROL
MAINTENANCE UNITS
BURGLAR ALARMS
FIRE ALARMS
ETC.

FIGURE 4
TERMINAL WITH OPEN-CHANNEL AND PREMIUM TV CHANNEL MODES

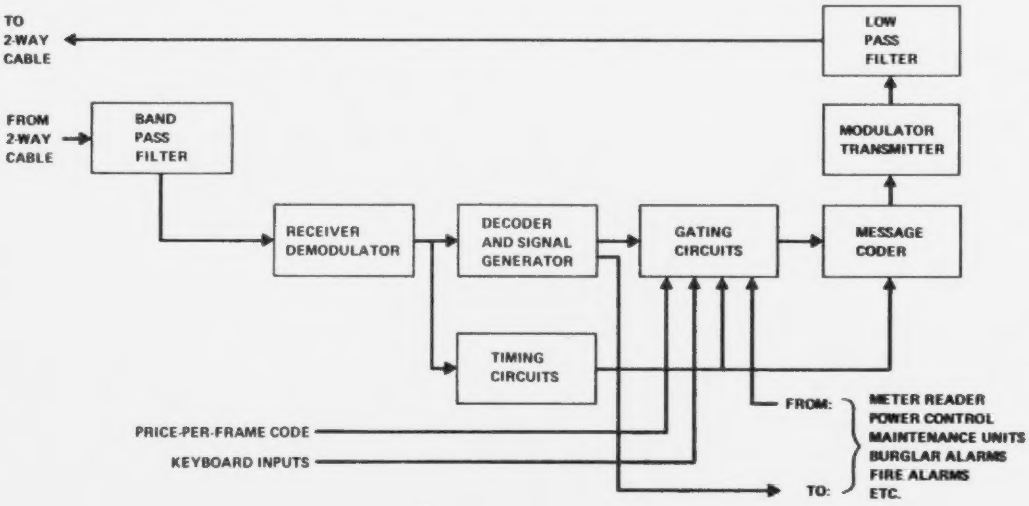

TO 2-WAY CABLE
LOW PASS FILTER
FROM 2-WAY CABLE
BAND PASS FILTER
MODULATOR TRANSMITTER
RECEIVER DEMODULATOR
DECODER AND SIGNAL GENERATOR
GATING CIRCUITS
MESSAGE CODER
TIMING CIRCUITS
PRICE-PER-FRAME CODE
KEYBOARD INPUTS
FROM:
TO:
METER READER
POWER CONTROL
MAINTENANCE UNITS
BURGLAR ALARMS
FIRE ALARMS
ETC.

FIGURE 5
DETAILS OF SUBSCRIBER-RESPONSE UNIT

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HIGHLIGHTS
TECHNICAL SESSION
2:00 PM, TUESDAY, MAY 16

CABLE CHANNEL ALLOCATION

Session Chairman: Archer S. Taylor, Malarkey, Taylor & Associates

Speakers: Dr. Robert S. Powers, Office of Telecommunications, Dept. of Commerce, Wash.,D.C.

Nate Levine, Sammons Communications, Inc., Dallas, Texas

I. Switzer, Maclean-Hunter Cable TV Ltd., Rexdale, Ontario, Canada

Parker T. Ellsworth, Magnavox Co., Ft. Wayne, Ind.

Reporter: Harold Berman, Waterbury Community Antenna Inc., Waterbury, Connecticut.

1. "Channel Allocation Options" - Dr. Robert S. Powers

Dr. Powers defined a subset of tasks to be addressed by the Frequency Allocation Subcommittee of the Coordinating Committee for Cable Communication Systems of the IEEE--ifentifying the frequency allocation and assignment problems, describing the techniques for analyzing these problems, and making specific recommendations for one or more sets of frequency assignments within one or more sets of frequency allocations.

The subcommittee at present will not discuss two-way services. They are confining themselves to NTSC TV signals, the existing FM radio band and VHF coaxial cables where technical problems of frequency allocation are most severe. It would be of great value if critical standards for the cable-receiver interface could be developed and implemented. Analytical techniques described by the subcommittee should be applicable to channels of bandwidth other than 6 MHz. At present, there are nine frequency allocation plans under study--from use of set-top converters to a dual cable application. Dr. Powers summed up by stating a later full report will be made to the parent committee in IEEE.

2. "The Dilemma of Mixed Systems" - Nate Levine

Mr. Levine discussed the dilemma of mixed systems in which the operator changes his basic 12-channel system by adding several additional channels in the mid or super band frequency range. It must be noted that this should be attempted on systems where second order distortion is at a minimum.

Several problems that can occur in a "mixed system"--a mixture of subscribers with converters and subscribers without converters-- were discussed. The first discussed was oscillator leakage from the non-converter subscriber's TV set into a particular feeder line. Various slides were used to depict the oscillator frequencies of all VHF channels and their relationship to the affected mid band channels and the oscillator leakage of various TV receivers.

Another problem that faces the mixed system is called "image." Image frequencies are greater with expanded systems and it was pointed out that the mid band Channels E, F, and G are the only serious potential offenders at the present.

3. "Coherent Carrier State of the Art" - I. Switzer

Mr. Switzer introduced his topic by giving a brief description of the history of distortion problems, beginning with the five-channel system to the present; from windshield wiper effect to third order intermodulation. Mr. Switzer noted that cross modulation increases at a logarithmic rate while intermodulation increases at a very high rate with the increase of channels. (Note: During the question period, Mr. Ken Eaton stated that with the tests made, it was found the cross modulation is the dominate factor up to 16 channels; and after that, intermodulation becomes a dominate problem.)

The analysis of the distortion in CATV amplifiers by K. A. Simons leads to some potentially significant improvements in the quality of television pictures transmitted via CATV systems subject to amplifier distortion. If the spacing between adjacent visual carriers is properly controlled, a reduction in the visibility of many third order distortion products is likely. Further improvement is likely to be obtained if all visual carriers are harmonics of a 6 MHz master oscillator.

The cross-modulation factor could be reduced by the use of a suppressed carrier. A major approach would be to unload the amplifiers by 6 dB or more. Yet to be determined is the best place to upgrade the suppressed carrier.

Mr. Switzer summed up his paper by saying that, as we expand our frequency carrying ability, it will receive a much more sophisticated headend and definitely more knowledgeable personnel in the field.

4. "Subscriber Terminal Interface Requirements" - T. P. Ellsworth

Mr. Ellsworth selected four major topics for review:

1. Rejection Ratios for Unwanted Adjacent Channel Carriers
2. Local Oscillator Interference
3. Local Oscillator Stability
4. Receiver Noise Figure and Dynamic Range

It has been found that the majority of problems that a cable operator is faced with in reference to a subscriber is due to the factors noted above. It has been noted here that the manufacturers are taking into consideration the problems that the TV set owner faces with a fully loaded 12-channel system. Mr. Ellsworth discussed varying additions both in adding traps, filters, and other improved designs.

He goes on to state what basic requirements would be necessary for the manufacturers to have a standard that would fit into the parameters to eliminate a large amount of problems and no doubt fit into the requirements of the technical standards that are set, or will be set, to the cable operator.

CHANNEL ALLOCATION OPTIONS

Robert S. Powers
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Abstract

This paper is based on an interim report of the Frequency Allocation Subcommittee, of the Coordinating Committee for Cable Communication Systems, Institute of Electrical and Electronic Engineers.

The Subcommittee is to produce a background report on the general problems of frequency allocation and assignments in cable. The report should be useful to government regulatory and policy bodies, system planners and owners, and manufacturers of cable equipment, converters, and receivers. The present paper describes the nature and importance of the frequency planning problem, the general goals of the Subcommittee, the types of cable systems being considered, the criteria being used to evaluate characteristics of the various frequency assignment schemes, and the general allocation plan being used by the Subcommittee for purposes of discussion. An important side problem being addressed by the Subcommittee is that of potential interference between over-the-air radio systems and cable systems using the same frequencies.

Problem Definition

The Federal Communications Commission now requires that cable systems in major markets provide at least twenty television channels and some two-way services. Many system operators intend to provide even more television channels than the required twenty, in addition to other possible non-television "downstream" and "upstream" services. A major question facing the cable industry is how to deliver to the subscriber these additional services, over and above the twelve television channels assigned by the FCC for over-the-air transmission.

There are several basic ways to deliver these additional services by wire:

1. VHF coaxial cables: Coaxial cables operating in the range from a few megahertz to 300 or 400 MHz carry television signals, non-television one-way services, and "upstream" services, possibly all on the same cable. The spectrum available on such cables could be utilized to the maximum extent by delivering additional television and other services on frequencies not assigned for over-the-air television broadcasting. Alternatively, two or more cables could be used to deliver television signals on the "normal" channels used for television broadcasting*; non-television services could use either additional cables or non-television frequencies.

2. UHF transmission: Downstream television service in addition to the twelve FCC channels is supplied on those frequencies allocated by the FCC for UHF television broadcasting. Non-television services use other frequencies.

3. High frequency (HF) cables: Paired-wire or coaxial cables, capable of carrying only one or two television channels each, connect the subscriber to a local distribution center. Programming is selected by the subscriber by means of a switch at the local distribution center.

A little thought will convince one that the most critical point in the whole system, no matter which type of cable is used, is the interface between any subscriber-owned equipment and equipment owned by the cable operator. There are indeed technical problems associated with frequency arrangements within the cable system itself, but these can be solved independent of the 90 million existing TV receivers and the expected future subscriber terminals. Also, there is less need for industry-wide standardization of those "internal" solutions. But at the subscriber interface the cable operator must deliver a signal which can be received with good quality, and assure that no signals from the receiver interfere with the cable system itself or with the reception of other subscribers. And this must be done in such a way that the subscriber can move from one cable system to any other in the Nation without having to make a new investment in terminal equipment.

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* Hereinafter referred to as the "FCC channels."

Considering now only the VHF cables, there are at present two basic ways to supply more than twelve channels to existing receivers. Either multiple cables are used, with a switch to choose which cable is connected to the receiver, or a converter of some kind is used to translate cable signals to one of the FCC channels.

In the latter case, the most serious constraint arises when the cable system is to provide some subscribers with signals on only the FCC channels and is to provide other subscribers with extra services on additional channels. This situation can arise either because the extra services are "optional at extra cost" or because the system is in transition between 12-channel operation and operation with 20 or more channels. Clearly, if all subscribers are using converters, the system operator will use whatever frequency plan is appropriate to the converters. If no subscribers are using converters, the frequency plan is automatically fixed by the TV receiver. In the "mixed" case, the need for serving existing receivers may be a severe limitation on the usefulness of otherwise acceptable frequency plans.

Presently used converters may be block converters located within the cable system, but usually are "set-top" converters installed on the subscriber's premises. The cost of a set-top converter may vary between $20 and $50, no small fraction of the total cost of delivering service. This cost could be strongly reduced if the capability for tuning extra channels were incorporated into receivers especially designed for cable reception. Herein lies a compelling argument for standardization of frequency usage on VHF cable systems.

If the frequencies upon which TV channels are delivered by cable systems were to be standardized, the feasibility of marketing television receivers capable of receiving all the cable channels would be enhanced. The cable operator would find it less expensive to extend service to new subscribers and to expand the number of channels in his system. The subscriber with a "cable TV" receiver who moved from one community to another would be assured that his receiver would interface completely with the new system.

To be most effective, a channelling plan which would provide such extra channel capability should be used universally. A universal plan might be followed voluntarily by receiver manufacturers and cable operators, as in the case of the present universal IF standard, or it might be instituted by Federal action.

The National Cable Television Association (NCTA) has asked the Federal Communications Commission to adopt standards to promote the marketing of television receivers designed to interface with cable systems. At this time, the Commission has not given indication of its probable response.

To summarize, it would be of great value to the public, to the cable industry, and to manufacturers of cable equipment and home receivers if critical standards for the cable-receiver interface could be developed and implemented. Such standards would permit maximum flexibility for choice by subscribers and for innovation by cable operators and receiver manufacturers, while assuring compatibility at the interface between subscriber equipment and cable systems.

Frequency Allocation Subcommittee - Formation and Goals

The Coordinating Committee for Cable Communication Systems of the Institute for Electrical and Electronic Engineers, chaired by Archer Taylor, recognized that the literature does not contain a convenient body of technical information upon which to base any such standardization at the interface. Therefore, the Coordinating Committee formed a Frequency Allocation Subcommittee, and gave it the task of preparing a technical report on the various possible frequency plans which could be used on cable systems. The output of the Subcommittee's work will not itself be a standard for frequency allocations and assignments*; that task will be left for other bodies. But the report will be available to serve as source material for the construction of such standards. The report should be useful to government regulatory and policy bodies, system planners and operators, manufacturers of cable equipment, converters and receivers.

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* For purposes of this report, a "frequency allocation" is considered to be the specification of which large blocks of available spectrum will be used for what general purposes, such as"NTSC television signals" or "upstream services." A "frequency assignment" is considered to be the specification of precisely how the large blocks designated by the "allocation" will be divided into individual channels.

The author of this paper chairs the Frequency Allocation Subcommittee at the present time. The Subcommittee consists of some 22 members, whose professional affiliations include cable system operators, cable system equipment manufacturers, television receiver manufacturers, converter manufacturers, not-for-profit corporations, and government.

This paper is based on an interim report of the Frequency Allocation Subcommittee to the parent Coordinating Committee, and as such does not represent the work of the author alone. However, this paper is not itself the work of the Subcommittee, so its author must take the blame for any errors or misrepresentations of the Subcommittee's thinking.

It was recognized very quickly that the sum total of all problems of frequency usage in all of the possible types of cable systems was enough to overwhelm the small Subcommittee. Thus, the Subcommittee defined a subset of problems, which it believes can be sensibly addressed at the present time and which the Subcommittee is competent to attack.

The tasks to be addressed at this time are as follows:

1. Identify the frequency allocation and assignment problem involved in adding downstream channels to the FCC channels and the FM radio band on VHF cable distribution systems, assuming that the cable system is to ultimately feed television receivers capable of receiving only the FCC channels.

2. Describe techniques for analyzing these problems and evaluating the various possible solutions. The techniques are to be applicable to channels of 6 MHz bandwidth, as well as to channels of wider and narrower bandwidths which will be used for services other than NTSC television.

3. Make specific recommendations for one or more sets of frequency assignments within one or more sets of frequency allocations.

Note that in its initial report, the Subcommittee will not discus in detail any two-way services, although it is well recognized that two-way capability exists now on some systems and will be widespread in the future. It is assumed that two-way services will either be carried on cables other than those carrying downstream television or will occupy distinct blocks of the cable spectrum, and that there will be no mutual interference between upstream and downstream services. Thus, downstream television service can be considered by itself.

The Subcommittee has also limited its initial considerations to delivery of standard NTSC television signals and the existing FM radio band. Thus, with the exception of the FM band, channels of width greater or less than 6 MHz are not being explicitly addressed. The rationale for this restriction is two-fold: (1) It is assumed that most of the downstream cable spectrum will be used for NTSC television signals; and (2) useful channels of bandwidth other than 6 MHz can often be made up of exact multiples or sub-multiples of 6 MHz. In any case, analytical techniques described by the Subcommittee should be applicable to channels of bandwidth other than 6 MHz.

Finally, the Subcommittee is concentrating most of its initial efforts on the problems of VHF coaxial cable systems, rather than on UHF and HF systems. The remainder of this paper is entirely directed to VHF systems. This emphasis is not meant to reflect in any way on the advantages or disadvantages of the HF and UHF systems. The VHF systems were chosen for the initial effort because: (1) most existing CATV systems in this country are VHF systems, and (2) the technical problems of frequency utilization (as contrasted with transmission and other technical problems) seemed most severe in the case of the VHF systems*.

Factors Affecting Cable Frequency Allocations

The first consideration in selecting a frequency plan is the number of channels which can be delivered with high quality. The delivery capability of a system which, in other respects has adequate bandwidth, generally is limited by signal degradation caused by the following:

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* A paper summarizing the considerations vis-a-vis the use of UHF for the final distribution of subscriber services is being drafted for the Subcommittee by one of its members, but will not be discussed here. That draft may represent the starting point for another phase of Subcommittee activity.

(1) Impairments due to distortion products generated within the cable network. (Example: Intermodulation products.)

(2) Interference to a subscriber's reception due to signals picked up by the system. (Example: Midband land mobile signals picked up by the cable equipment.)

(3) Interference to a subscriber's reception due to signals injected into the system by other subscribers' receivers. (Example: Receiver local oscillator signals.)

(4) Interference to a subscriber's reception by external signals picked up by the subscribers' own receiver. (Example: Strong ambient fields from local co-channel television stations.)

The Subcommittee is examining both the theoretical maximum number of channels available with each frequency plan and the degree of interference likely to occur in each system. The severity of impairment is largely a matter of equipment design, operating adjustments, and proximity to local high powered interfering transmitters. The number of opportunities for picture impairment can be minimized by choice of the proper channel assignment plan.

A second major consideration in some cases is the performance of the system in the "mixed" operating mode mentioned above: in the mixed mode some subscribers have converters, and other subscribers connect receivers directly to the cable system. The Subcommittee is using two primary indicators for evaluating frequency plans under this consideration: (1) The number of channels a subscriber can receive without a converter, and (2) implications of the frequency plan for the design of a special receiver for both cable and over-the-air reception. The possibilities of varactor tuning, automatic channel identification, and other advances should be considered in the conceptual design of such receivers.

The performance of present-day (unshielded) receivers operating in strong signal areas must also be considered, at least for the next 5 to 10 years. The number of channels which would be unusable because of local pick-up is being used to evaluate this aspect of proposed frequency plans.

The final major technical consideration being examined by the Subcommittee is the tuning of the receiver or the receiver-converter combination to the desired channel. The type of converter and the number and type of controls which must be used to tune channels is noted. The overall ease of tuning is the important factor to the subscriber. At the present time, the Subcommitte can only make subjective judgments of this important factor. Some type of consumer testing may be needed to fully evaluate the ease of tuning, although it is clear that a special cable receiver could have simpler tuning controls than any receiver-converter combination.

Of course, the total system cost, which will eventually rest on the subscriber in any case, is a vital factor. These costs include costs of first implementation, costs inherent in future expansion requirements, maintenance costs for equipment and plant, and possibly the cost to the public of new subscriber-owned receivers. The Subcommittee will draw general cost implications, but may not be able to make detailed determinations.

Assumptions

In planning for future usage of cable networks, certain assumptions must be made regarding the circumstances under which they must operate. Assumptions which are believed applicable to nearly all situations are set forth below*:

(1) The primary function of the cable system is to deliver off-air and locally originated television programs to subscribers located downstream from some common collection or control point (such as a head end.)

(2) Frequency space and amplitude range within the system is available for other services of unspecified type, which may or may not flow upstream from subscribers, but which must afford protection to downstream TV.

(3) The number of channels which the cable must carry simultaneously must be 20 or more.

(4) Subscribers should at all times receive pictures with minimum distortion and interference and, in no case, of poorer than "passable" quality (by TASO definition).

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* In certain circumstances, some of the basic assumptions may be erroneous. For example, it is yet too early to expect that all subscriber receivers are capable of satisfactory operation in very strong ambient co-channel fields. Such variances must be recognized and allowed for in planning individual cable systems, at least for the next 5 to 10 years.

(5) The ultimate destination of the television signals will be the subscriber-owned television receiver which is presumed to have a capability as follows:

(a) Only channels in the VHF range will be used for receiving signals from the cable system.

(b) All sets will accommodate simultaneous use of adjacent channels on the cable.

(c) All sets will operate satisfactorily in an ambient co-channel field of up to 500 mV/m.

(d) All color sets have phase characteristics suitable for high quality color television.

(e) All sets use the standard 45.75 MHz IF.

(6) Where converters are used, those converters are assumed to have characteristics which obviate co-channel (local pick-up), adjacent channel and image channel problems, and do not transmit interfering signals back into the cable*.

Alternate Frequency Plans

The major technical problems of frequency planning are associated with the detailed channel assignments rather than with the general nature of the broad allocation plan. Thus, the Subcommittee has simply adopted for its own reference a single one of the many possible allocation plans. This plan is represented by Table 1. Changes in this allocation plan could, of course, require adjustments in the detailed channel assignments. But the evaluation criteria and technical problems being identified by the Subcommittee would remain valid.

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* For example, a double conversion scheme with a first IF higher than 300 MHz is one possible way to meet this assumption.

Each of the basic channel assignment plans considered in some detail by the Subcommittee is described briefly below. There are large numbers of possible variations, of course, but the plans below illustrate the basic approaches that have come to the attention of the Subcommittee.

Plan A.

Consists of the 12 FCC channels, to which 9 midband channels have been added. These continuously fill the frequency band between 120 and 174 MHz, and are transmitted in upright fashion (sound carrier above the video carrier.)

Total TV channels: 21
Maximum number available without converter: 12
Channels lost due to local pick-up, using converter: none
Channels lost due to local pick-up, not using converter: N(low) + N(hi)*
Method of tuning: Tune converter

Considered attractive for existing systems, since existing active and passive hardware will cover the midband range. Addition of the midband channels to the system causes substantial build-up of second and third order distortion products on all channels, and invites interference on channels 7 - 13 from local oscillator signals injected into the system from receivers not isolated by a converter.

Plan A-1.

12 FCC channels to which 9 midband and 9 superband channels have been added. These, plus the FCC channels 7 - 13, continuously fill the frequency band between 120 and 270 MHz, and are transmitted in upright fashion.

Total TV channels: 30
Maximum number available without converter: 12
Channels lost due to local pick-up, using converter: none
Channels lost due to local pick-up, not using converter: N(low) + N(hi)
Method of tuning: Tune converter

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* N(low) is the number of strong local signals in the low VHF band. N(hi) is the number in the high band.

A frequently recommended next step after filling the midband channels. Extending the frequency range of amplifiers and passive devices in the cable network substantially above 216 MHz may prove difficult. Attenuation increases, securing the additional gain needed at wider bandwidths may be difficult, and the number of second and third order distortion products caused by the additional loading increases substantially

Plan A-2.

12 FCC channels to which 8 midband and 8 superband channels have been added. These are arranged to reduce the incidence of beats from receiver local oscillators and to reduce image interference possibilities. Transmitted upright.

Total TV channels: 28
Maximum number available without converter: 12
Channels lost due to local pick-up, using converter: none
Channels lost due to local pick-up, not using converter: N(low) + N(hi)
Method of tuning: Tune converter

A variation of Plan A-1 in which some of the midband and superband channels have been staggered to reduce the effects of interfering distortion components and local oscillator signals. Although certain of the more destructive distortion components are moved to frequencies where their effects will be less discernible, the number of possible distortion products seems to increase.

Plan A-3.

20 Channels arranged in the octave 120 - 240 MHz. Transmitted upright.

Total TV channels: 20
Maximum number available without converter: 7
Channels lost due to local pick-up, using converter: none
Channels lost due to local pick-up, not using converter: N(hi)
Method of tuning: Tune converter

Because of using a single octave, second order products fall below the lowest channel and above the highest, easing system design.

Plan B.

12 FCC channels to which 7 midband and 7 superband channels have been added. The latter two groups are transmitted in inverted fashion, permitting block conversion with the converter local oscillate frequency above the group of converted channels.

Total TV channels: 26
Maximum number available without converter: 12
Channels lost due to local pick-up, using converter:
N(low) + 3 N(hi)
Channels lost due to local pick-up, not using converter:
N(low) + N(hi)
Method of tuning: Converter switch plus tuning of receiver

By proper selection of the local oscillator frequencies in the block converter, the midband and superband channels can be positioned so that local oscillator signals injected into the system by subscriber-owned receivers will fall at channel edges, substantially reducing their effect on the picture.

Plan C.

24 channels spaced with visual carriers 9.5 MHz apart, starting at 52.25 MHz. Transmitted upright.

Total TV channels: 24
Maximum number available without converter: none
Channels lost due to local pick-up, using converter: none
Channels lost due to local pick-up, not using converter: n.a.
Method of tuning: Tune converter

Second order components are made to fall in the guardband between channels. However, third order products fall on or close to visual carrier frequencies where interference is most critical.

Plan D.

30 channels, with all video carriers being placed at integral multiples of 6 MHz and phase-stabilized with reference to a common frequency source. Transmitted upright.

Total TV channels: 30
Maximum number available without converter: none
Channels lost due to local pick-up, using converter: none
Channels lost due to local pick-up, not using converter: n.a.
Method of tuning: Tune converter

All second and third order distortion products of the carriers fall precisely on the frequencies of other carriers, where they manifest themselves as fixed-phase contributions to the carrier of the desired signal. Unless the synchronizing rate of all signals in the systems is also phase-stable, much of the benefit promised by this plan may not be achieved.

Plan E.

34 contiguous channels, between 66 MHz and 270 MHz. Transmitted inverted. Presumes use of a single oscillator in the converter, with converter output at FCC channel 2 or 3.

Total TV channels: 34
Maximum number available without converter: none
Channels lost due to local pick-up, using converter: none
Channels lost due to local pick-up, not using converter: n.a.
Method of tuning: Tune converter

Since only a single conversion is required, converter design is simplified, and cost may be reduced. Converter oscillator frequencies fall on channel edges, minimizing stability problems and reducing interference possibilities. Second order difference products also fall on channel edges, but sum products produce a 1.25 MHz beat with the visual carrier. Third order products fall directly on visual carrier frequencies. Visual carriers from image channels may produce 3.5 MHz beats. Since the lowest downstream channel starts at 66 MHz, the design of filters for separating the lower frequency upstream signals is eased, permitting either the use of lower-cost filters or a greater utilization of the upstream spectrum.

Plan F.

Two separate VHF cables, each carrying 12 FCC channels. Transmitted upright. An A/B switch at the receiver is used to select the cable to be connected to the receiver.

Total TV channels: 24
Maximum available without converter: n.a.
Channels lost due to local pick-up, using converter: n.a.
Channels lost due to local pick-up, not using converter: 2N(low) + 2N(hi)
Method of tuning: A/B switch plus receiver tuning

All second order products fall outside of any downstream channel. The number of cross-modulation products is reduced by an order of magnitude compared to carrying the same total number of channels on a single cable.

The Potential for Cable/Over-the-Air Interference

It has been suggested that under certain conditions of faulty operation there could be interference to over-the-air services caused by signals "leaking" from cable systems. Such interference would not occur under normal conditions; there would have to be some break in the cable system and/or some radiating element improperly connected to the cable in order for any significant power to be radiated. Prohibiting the use within cables of frequencies assigned to services in the over-the-air spectrum could be a very costly burden for the cable industry to bear. It would not then be possible to utilize fully the capability of the VHF coaxial cables, which are expected to be widely used in the industry.

The Subcommittee felt that no responsible study of full utilization of VHF cables could ignore the possibility of such interference, even though some first estimates make the chance of harmful interference seem remote. Therefore, the Subcommittee requested and is receiving the assistance of appropriate Federal agencies in defining and investigating this potential.

The Federal Aviation Administration, Department of Transportation, has thoughtfully outlined the conditions under which it questions whether interference could occur. The Office of Telecommunications, Department of Commerce, has assumed the lead role in a technical study of whether any such interference is likely or even possible. This study will include theoretical analysis, laboratory investigations, and possibly field trials. The Office of Telecommunications Policy, Executive Office of the President, is also participating in the study, because of its responsibility for frequency management for Federal government radio users. The OTP is actively encouraging the investigation, participating in planning and discussions, and has assured the Subcommittee of its deep interest in reaching a sound conclusion as to whether interference could possibly occur, and if so how it might be prevented.

Acknowledgements

The working papers of the Subcommittee, on which this report is based, are the work of many individuals. But, special credit is due to Sydney R. Lines, who has drafted a working paper which summarizes the Subcommittee work to date. Lines' summary is the basis for this discussion, and will be the basis for a later full report to the parent Committee in IEEE.

Table I

Subcommittee Working Allocation Plan for VHF Cables

Frequency band (MHz)	Allocation	Possible Uses
Below 54	EXPERIMENTAL	Television Subscriber response signals Telemetry Facsimile Control of monitoring signal
54 - 72	TELEVISION	Cable television, classes I and II
72 - 76	EXPERIMENTAL	Pilot signals Control signals
76 - 88	TELEVISION	Cable television, classes I and II
88 - 108	AURAL BROADCAST	FM Broadcast signals AM Broadcast signals, remodulated to FM Local origination, FM
108 - 120	EXPERIMENTAL	Subscriber interrogation signals Control signals Pilot signals
120 - 174	TELEVISION	Cable television, classes I and II
174 - 216	TELEVISION	Cable television, classes I and II
216 - 270	TELEVISION	Cable television, classes I and II
270 - 300	EXPERIMENTAL	Cable television, classes I, II and III Facsimile
300 - 400	EXPERIMENTAL	Cable television, class IV Telemetry Subscriber response signals Monitoring signals
Above 400	Not Allocated	

THE DILEMMA OF MIXED SYSTEMS

Nate Levine
Vice President, Engineering
Sammons Communications, Inc.

Most of us who operate cable systems and are providing twelve channels of service to our customers at a fixed fee have probably considered, at one time or another, the possibility of adding several additional channels in the mid or super band frequency range, providing converters to customers who desire these channels and charging an additional $2-$3 per month for this service. At the onset, this does not look like a difficult task since most cable systems today already have the necessary band width to carry mid band frequencies and most new systems being installed today have extended bands with widths of 260 or even 300 MHz.

At this point in time, it should be apparent to most of us that this should only be attempted on systems where second order distortion is at a minimum, such as a push-pull system. For the purpose of this presentation, we will assume that second order problems are non-existent and explore the other problems that arise when mid band and super band channels are added.

If only a portion of the total system subscribers request the extra services, we become faced with the problems of a "mixed system". It is categorized as mixed because it is a mixture of subscribers with converters and subscribers without converters. Under these conditions, several problems can occur. The first to be discussed is oscillator leakage from the non-converter subscriber's TV set into a particular feeder line.

Table I depicts the conventional mid band and super band video carrier frequencies.

TABLE I

CHANNEL MID BAND	VIDEO CARRIER	CHANNEL SUPER BAND	VIDEO CARRIER
A	121.25	J	217.25
B	127.25	K	223.25
C	133.25	L	229.25
D	139.25	M	235.25
E	145.25	N	241.25
F	151.25	O	247.25
G	157.25	P	253.25
H	163.25		
I	169.25		

Table II depicts the television receiver oscillator frequencies of all VHF channels and their relationship to the affected mid band channels.

TABLE II

VHF CHANNEL	OSCILLATOR FREQUENCY (MHz)		MID BAND CHANNEL CARRIERS	INTERFERING BEAT
2	101			
3	107			
4	113			
5	123	MID BAND	A = 121.25	1.75 MHz
6	129		B = 127.25	1.75 MHz
7	221		J = 217.25	3.75 MHz
8	227		K = 223.25	3.75 MHz
9	233	SUPER BAND	L = 229.25	3.75 MHz
10	239		M = 235.25	3.75 MHz
11	245		N = 241.25	3.75 MHz
12	251		O = 247.25	3.75 MHz
13	257		P = 253.25	3.75 MHz

As can be seen from this table, television sets tuned to Channels 5 or 6 have oscillator frequencies that are in the mid band spectrum. It can also be noted from Table II that all the high band channels have oscillator frequencies falling in the band commonly referred to as super band, frequencies 216-260. These frequencies appear at the antenna terminal points of a TV receiver and travel back into the feeder line.

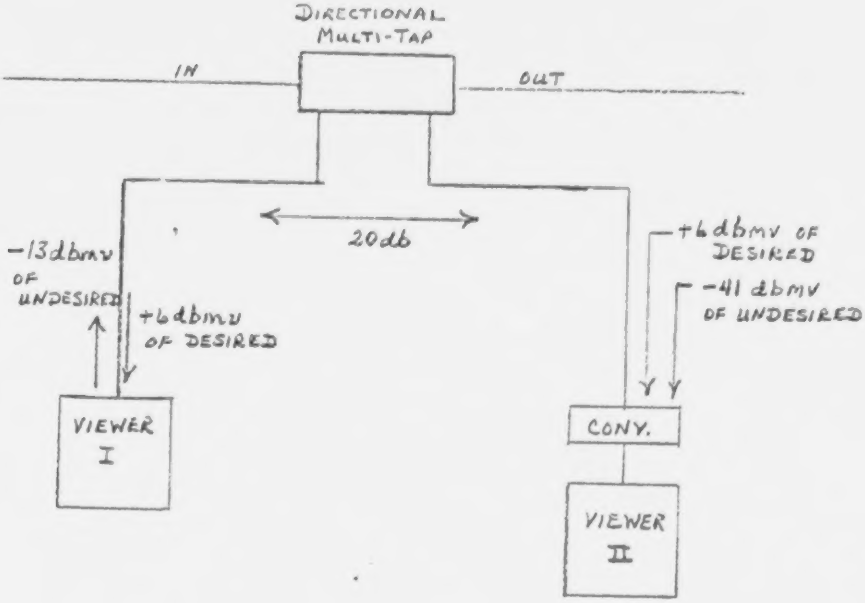
Table III shows the amount of oscillator signal available at the antenna terminal of various TV receivers tested.

TABLE III[1]
OSCILLATOR LEAKAGE OF VARIOUS TELEVISION RECEIVERS

CHANNEL	RECEIVER A	RECEIVER B	RECEIVER C	RECEIVER D	RECEIVER E	RECEIVER F
4	-22.0	-12.0	-15.0	-12	-13.0	-24.0
5	-14.0	+ 2.0	-13.0	-11	- 8.0	-30.0
6	-11.0	+ 4.0	-13.0	- 9.5	- 7.5	-30.0
7	- 3.0	+19.0	- 4.0	+ 6	- 3.0	-18.0
8	+ 1.0	+21	- 4.0	+ 5.5	- 1.5	-14.0
9	+ 1.0	+21	- 2.0	+ 8.0	- 2.0	-10.0
10	0.0	+24.5	- 3.0	+ 9.0	- 4.0	-20.0
11	- 3.0	+20.0	- 4.0	+10.0	- 8.0	-20.0
12	- 7.0	+11.0	0.0	+ 8.0	- 3.0	-11.0
13	- 5.0	+10.0	- 1.0	+ 6.0	- 4.0	-12.0

Figure 1 is a diagram of two subscribers receiving signal through a directional multi tap.

FIGURE 1



Viewer 1 does not have a converter and is tuned to Channel 5 using TV Receiver Set C which has an oscillator leakage of -13 dbmv. Viewer 2 is tuned to Channel A. Both lines are delivering +6 dbmv of desired signal.

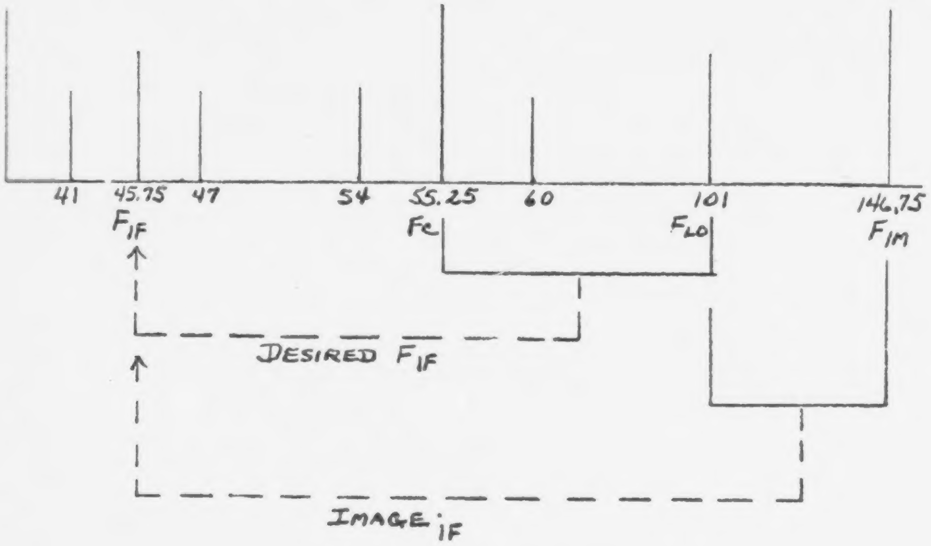
Viewer 1 originates on 123 MHz carrier at -13 dbmv. The oscillator signal travels up the drop line losing approximately 4 db. It travels through the directivity of the coupler, approximately 20 db, and down converter's B drop line, losing an additional 4 db. Total loss of undesired signal: 4 + 20 + 4 = 28. Oscillator leakage signal appearing at Viewer 2 is, therefore, -41 dbmv (-13 dbmv from Viewer 1 oscillator + 28 db of loss). Ratio between desired +6 dbmv and undesired -41 dbmv = 47 db.

Video carrier Channel A at Viewer 2, beating with undesired signal at 123 MHz, produces a 1.75 MHz beat, 47 db below the desired signal. This type of beat, because of its proximity to the desired video carrier, must be at least 60 db down for it not to be objectionable.

Referring back to Table III, you will note that TV Receiver Set C having an oscillator leakage of -13 dbmv was chosen. You will note that other TV receivers have oscillator signals as high as +2 dbmv. This much leakage would produce a beat only 32 db down.

Another problem that faces us when we carry more than twelve channels on a cable system is one called "image". The image frequency of a receiver is defined as the desired signal ± two times the receive IF. This is best shown by Figure 2.

FIGURE 2



Here we see desired Channel 2 at 55.25 MHz beating with the local oscillator signal at 101 MHz to produce IF at 45.75. Also observe that a signal at 146.75 can beat with the local oscillator to produce the desired IF signal. The 146.75 MHz frequency is referred to as Channel 2's image. Its presence into the receiver's IF is limited by the tuner's image rejection capability. Image rejection typically runs as follows:

A. 3 circuit tuners: used in low cost TV sets
   low band 50 db
   high band 35 db
B. 4 circuit tuners: used in better black and white sets and color sets
   all VHF channels 60 db

Let us now explore the possible image problems. Table IV depicts all the VHF carriers' image frequencies and interference possibilities.

TABLE IV

CHANNEL	VIDEO CARRIER (MHz)	IMAGE FREQUENCY	BEAT	CAUSE
2	55.25	146.75	1.5 MHz	E Video
3	61.25	152.75	1.5 MHz	F Video
4	67.25	158.75	1.5 MHz	G Video
5	77.25	168.75	-.5 MHz	I Video
6	83.25	174.75	-.5 MHz	7 Video
7	175.25	266.75		
8	181.25	272.75		
9	187.25	278.75		
10	193.25	284.75		
11	199.25	290.75		
12	205.25	296.75		
13	211.25	302.75		

It should be noted that mid band Channels E, F and G are the only serious potential offenders since Channel 7 and I Video carriers produce a negative beat in relationship to the desired carrier. A negative beat is less objectionable because of the added attenuation offered by its position on the IF slope in a TV receiver. High band channel images fall 266 to 305 MHz and are not a problem until that portion of the band is used.

Let us now summarize our potential problems: (1) ... the mid band, we are faced with oscillator leakage problems from Channels 5 and 6 into Channels A and B and image problems into Channels 2, 3 and 4 caused by E, F and G Video; (2) In the super band, oscillator leakage from Channels 7 through 13 affects Channels J through P, but image problems are non-existent.

What are the possible solutions to these problems when we try to operate a mixed system? The simplest solution would be to carry only Channels C, D, H and I in the mid band since these are the only channels that are not affected by local oscillator and image problems. Another suggestion that would permit us to carry mid band Channels A and B would be to delete Channels 5 and 6 or carry material on Channels 5 and 6 that is not significantly viewed such as the weather scan. Still another possible solution is to supply mid band band-stop filters and super band band-stop filters to non-converter subscribers. The mid band filters would eliminate the local oscillator feedback into the system, and the super band band-stop filters would not allow the images of the VHF channels into the subscribers' TV sets. The problems of this solution should be apparent. Perhaps the best solution is to carry a limited number of out-of-band channels and carefully select the frequencies so that the offending beats fall in a less objectionable portion of the IF curve.

To date, we can only speculate on the magnitude of the problems discussed since there are not enough "mixed" cable systems in operation for us to gather sufficient data. It is quite possible that image rejection of most TV sets will be sufficient. Perhaps as more extended band systems are built and additional channels are added, the proper solution will become self-evident.

---

[1] Jeffers, Mike, "Best Frequency Assignments for Mid Band and Super Band Channels", 19th Convention Transcript, Page 66-78.

TABLE I

CHANNEL MID BAND	VIDEO CARRIER	CHANNEL SUPER BAND	VIDEO CARRIER
A	121.25	J	217.25
B	127.25	K	223.25
C	133.25	L	229.25
D	139.25	M	235.25
E	145.25	N	241.25
F	151.25	O	247.25
G	157.25	P	253.25
H	163.25		
I	169.25		

TABLE II

VHF CHANNEL	OSCILLATOR FREQUENCY (MHz)	MID BAND CHANNEL CARRIERS	INTERFERING BEAT
2	101		
3	107		
4	113		
5	123	A = 121.25	1.75 MHz
6	129	B = 127.25	1.75 MHz
7	221	J = 217.25	3.75 MHz
8	227	K = 223.25	3.75 MHz
9	233	L = 229.25	3.75 MHz
10	239	M = 235.25	3.75 MHz
11	245	N = 241..25	3.75 MHz
12	251	O = 247.25	3.75 MHz
13	257	P = 253.25	3.75 MHz

TABLE III
OSCILLATOR LEAKAGE OF VARIOUS TELEVISION RECEIVERS

CHANNEL	RECEIVER A	RECEIVER B	RECEIVER C	RECEIVER D	RECEIVER E	RECEIVER F
4	-22.0	-12.0	-15.0	-12	-13.0	-24.0
5	-14.0	+ 2.0	-13.0	-11	- 8.0	-30.0
6	-11.0	+ 4.0	-13.0	- 9.5	- 7.5	-30.0
7	- 3.0	+19.0	- 4.0	+ 6	- 3.0	-18.0
8	+ 1.0	+21	- 4.0	+ 5.5	- 1.5	-14.0
9	+ 1.0	+21	- 2.0	+ 8.0	- 2.0	-10.0
10	0.0	+24.5	- 3.0	+ 9.0	- 4.0	-20.0
11	- 3.0	+20.0	- 4.0	+10.0	- 8.0	-20.0
12	- 7.0	+11.0	0.0	+ 8.0	- 3.0	-11.0
13	- 5.0	+10.0	- 1.0	+ 6.0	- 4.0	-12.0

FIGURE 1

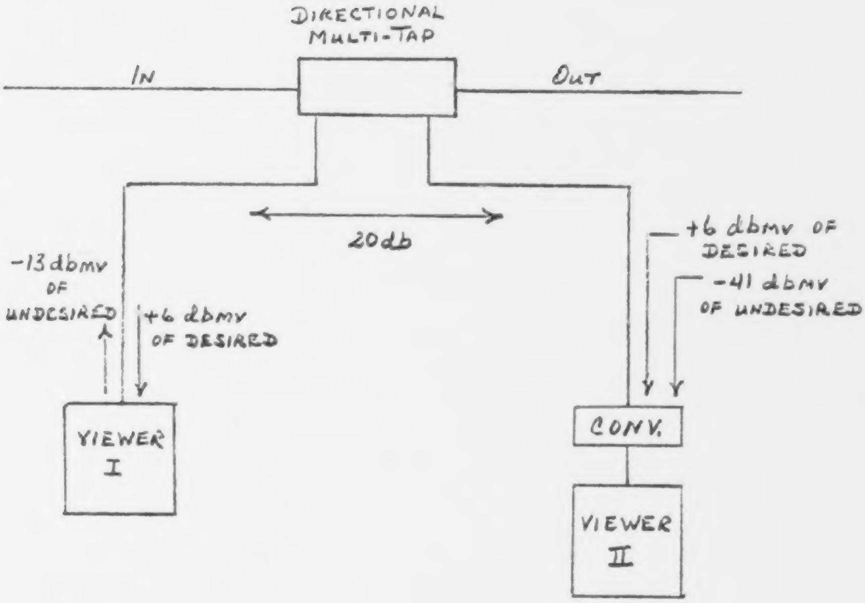

DIRECTIONAL MULTI-TAP
IN
OUT
20db
-13 dbmv OF UNDESIRED
+6 dbmv OF DESIRED
+6 dbmv OF DESIRED
-41 dbmv OF UNDESIRED
VIEWER I
CONV.
VIEWER II

FIGURE 2

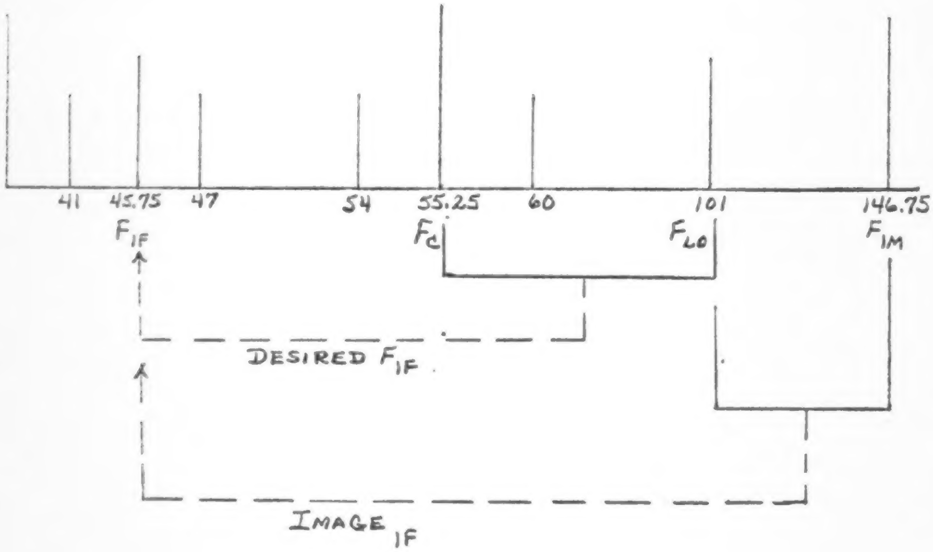

41
45.75
47
54
55.25
60
101
146.75
F_{IF}
F_C
F_{LO}
F_{IM}
DESIRED F_{IF}
IMAGE $_{IF}$

TABLE IV

CHANNEL	VIDEO CARRIER (MHz)	IMAGE FREQUENCY	BEAT	CAUSE
2	55.25	146.75	1.5 MHz	E Video
3	61.25	152.75	1.5 MHz	F Video
4	67.25	158.75	1.5 MHz	G Video
5	77.25	168.75	-.5 MHz	I Video
6	83.25	174.75	-.5 MHz	7 Video
7	175.25	266.75		
8	181.25	272.75		
9	187.25	278.75		
10	193.25	284.75		
11	199.25	290.75		
12	205.25	296.75		
13	211.25	302.75		

COHERENT CARRIERS FOR CATV - STATE OF THE ART

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ABSTRACT

Distortion in CATV amplifiers has been analyzed by several authors, notably Simons (1) who calculated the decibel relationships between various types of distortion products. Consideration of the practical implications of such an analysis leads to some potentia-ly significant improvements in the subjective quality of television pictures transmitted through cable television systems subject to amplifier distortion. A reduction in the visibility of many third order distortion products is likely if the spacing between adjacent visual carriers is properly controlled. A further improvement is likely to be obtained if all visual carriers are harmonics of a 6 MHz master oscillator. In such a case all second and third order distortion products are "zero-beat" and it is suggested that the subjective effect of interference in such a case would be substantially lower than is presently the case with present visual carrier frequency allocations.

The use of harmonic, coherent carriers will improve system performance and will also make possible some simplification of receiver tuners and converters.

INTRODUCTION

CATV amplifier distortion is commonly analyzed in the form of a power series expression with three terms (1). Such an analysis gives rise to distortion terms that include second and third order harmonics and intermodulation products and double and triple beat products. Additional distortion terms describe cross modulation. DC shifts and gain expansion or compression also arises in the analysis but these effects may be considered very minor in practical CATV amplifiers.

Second order distortion components consist of second harmonics of the input signals and sum and difference products of the input signals. Third order distortion products consist of cross modulation, intermodulation, triple-beat terms, and third harmonics. Intermodulation is considered to be the interaction between two input frequencies. The third order intermodulation term of concern in this discussion is the one having the forms $2F_1 + F_2$ and $2F_1 - F_2$ Triple beat terms of concern here take the forms $F_1 + F_2 + F_3$, $F_1 - F_2 - F_3$, $F_1 + F_2 - F_3$ and $F_1 - F_2 + F_3$.

Aural carriers in cable television systems are usually run about 15 db below associated or next higher adjacent visual carrier. At these levels they are not considered as contributing to the distortion products in a cable television system and are usually omitted from analyses of the distortion problem

DISTORTION PRODUCTS IN PRACTICAL CABLE SYSTEMS

Second order distortion products do not interfer with the operation of conventional twelve channel cable systems since all harmonics, sums and difference of the twelve regular VHF television visual carriers fall outside the regular VHF bands. Second order distortion products do, however, seriously affect the operation of augmented cable systems carrying more than twelve channels. As examples we may note that second harmonics of low band carriers fall into the mid band, second harmonics of mid-band channels fall into the super-band. Differences between high band and super-band carriers fall into the low band. Sums of mid-band and low-band carriers fall into the high band.

Many CATV amplifiers in current use were designed to minimize third order distortion products, particularly cross-modulation, with no particular regard to the amplifier's second order distortion characteristics. It now becomes virtually impossible to add additional channels in such systems.

Third order distortion affects practical cable systems in several ways. The effects of cross-modulation are well-known and amplifier design has concentrated on the minimization of this particular distortion. Other forms of third order distortion products affect conventional twelve channel systems, but their effect on subjective picture quality is not clearly understood.

Third order harmonics of low band channels may be a problem in some amplifiers. Table I lists these harmonics:

TABLE I

Channel	Visual Carrier	Third Harmonic	
2	55.25 MHz	165.75 MHz	(mid-band)
3	61.25	183.75	(channel 8)
4	67.25	201.75	(channel 11)
5	77.25	231.75	(super-band)
6	83.25	249.75	(super-band

Simons states that third harmonics will be 15.5 db lower in voltage level than a triple beat component arising from input signals of the same voltage level. Because of the relatively low level of third order harmonics, visible interference from them is probably rare.

Triple beat products are probably significant contributors subjective picture quality degradation in practical cable systems. A discussion of these products should be separated into "near" and "distant" products. Triple beat terms in which both signs are either + or - will give rise to products relatively distant in frequency from the input signals being considered. Triple beats with alternating signs give rise to products quite near to the input signal frequencies.

It is obvious that there is a very large number of distortion products in a multi-channel cable system. Muller (2) has calculated and tabulated some of the second and third order distortion products generated in a conventional twelve channel system which fall within the standard twelve channels. He tabulates a total of 353 distortion products arising in a twelve channel system and falling within the twelve channels. In an augmented channel system the number is considerably more.

Near triple beats in a group of adjacent channels fall close to a visual carrier. The "near" triple beats between channels 9, 10 and 11 illustrate this:

9V + 10V - 11V = 187.25 + 193.25 - 199.25 = 181.25 MHz (8V)

9V - 10V + 11V = 187.25 - 193.25 + 199.25 = 205.25 MHz (12V)

The "near" triple beats between channels 9, 10 and 11 fall on channels 8 and 12. Similar results are obtained from other combinations of channels from an adjacent "group" when taken three at a time. Some of the "near" products fall immediately above or below the group, and if the group considered is the standard "high band" they would fall onto mid-band or super-band channels.

In a practical cable system the visual carrier frequencies are only nominally 1.25 MHz above the lower band edge. The actual visual carrier frequency depends on the offset assigned to the originating station, the accuracy to which a particular transmitter holds its operating frequency and the accuracy and stability of any frequency conversions which the cable system itself may make. Table II illustrates the variation that may be experienced in a practical cable system.

TABLE II

Channel	Visual carrier 10 a.m.	Visual carrier 4 p.m.	Note
2	55.25007 MHz	55.25007 MHz	Broadcast channel
3	61.26007	61.26010	Broadcast channel
4	67.23998	67.23997	Broadcast channel
5	77.25105	77.25094	Conversion 6 - 5
6	83.26031	83.26026	Modulator locked to 6
7	175.25994	175.25995	Broadcast channel
8	181.24342	181.24342	Conversion 9 - 8
9	187.25004	187.25003	Modulator locked to 9
10	193.24460	193.24569	Substitution oscillator
11	199.25951	199.25952	Broadcast channel
12	205.24539	205.24524	Closed circuit modulator
13	211.22754	211.29307	Substitution oscillator at 10 a.m., UHF conversion from channel 19 at 4 p.m.

Variations from nominal visual carriers (4 p.m. observation) run from -10.03 KHz to + 43.07 KHz. The near triple beats and inter-modulation products can be expected to fall within a similar range from the nominal visual carrier which they affect.

To illustrate this effect a set of third order distortion products arising from the twelve carriers in the system at the 10 a.m. observation in Table II were calculated and observed on a spectrum analyzer. All the triple beat and intermodulation products which would fall near a hypothetical carrier at 49.25 MHz were calculated in Table III and arranged in order of increased frequency in Table IV.

TABLE III

2V + 2V - 3V = 49.24007 MHz

2V + 3V - 4V = 49.27106

2V + 5V - 6V = 49.24081

2V + 7V - 8V = 49.26660

2V + 8V - 9V = 49.24346

2V + 9V -10V = 49.25551

2V +10V -11V = 49.23517

2V +11V -12V = 49.26419

2V +12V -13V = 49.26792

3V + 7V - 9V = 49.26998

3V + 8V -10V = 49.25589

3V + 9V -11V = 49.25060

3V +10V -12V = 49.25928

3V +11V -13V = 49.29204

4V + 7V -10V = 49.25532

4V + 8V -11V = 49.22389

4V + 9V -12V = 49.24462

4V +10V-13V = 49.25704

TABLE IV

49.22389 MHz

49.23517

49.24008

49.24081

49.24346

49.24462

49.25060

49.25532

49.25551

49.25704

49.25889

49.25928

49.26419

49.26660

49.26792

49.26998

49.27017

49.29204

All these products were identified in the system using the spectrum analyzer and digital frequency counter.

Similar clusters of distortion products exist around every visual carrier in the system, the exact number depending on the channel and total number of channels being carried.

The beats resulting from these particular eighteen interfering products give rise to a complex visual effect. Differences between interference products range from about 800 Hz to 22 KHz. The author has not been able to find any reports of studies relating picture quality degradation to multiple interference of this kind and it is proposed to study the effect by eliminating it as proposed later in this paper.

The 4 Mhz guard band between channels 4 and 5 causes third order "near" products which are space at 4, 10 and 16 MHz above and below other carriers instead of the usual multiples of 6 MHz. These products fall 2 and 4 MHz above visual carrier, areas that are not as sensitive to interference as the area immediately adjacent to the visual carrier.

Some third order "distant" products are of concern. Three such examples are:

11V - 6V - 3V = 199.25 - 83.25 - 612.5 = 54.75 MHz

13V - 6V - 3V = 211.25 - 83.25 - 612.5 = 66.75 MHz

13V - 6V - 4V = 211.25 - 83.25 - 67.25 = 60.75 MHz.

There are five more triple beat combinations that will give the same nominal frequencies as the above examples. These will result in clusters of distortion products at the nominal interference frequencies. There are many other third order "distant" products which are generated in multi-channel systems. Some arise from the offset of channels 5 and 6 due to the 4 MHz guard band between channels 4 and 5. Others arise from combinations in which the signs combining terms are either both + or both -. Simons, in an unpublished memorandum, has studied the number of such "distant" terms in more detail. He cites two examples. In the first example, using ten "standard" channels (2-4, 7-13) there are 176 in-band, third order distortion products of which 25 are not close to carrier frequencies. In a second example he cites a 21 channel system using the "standard" 12 channels, except that channels 5 and 6 are moved up 2 MHz, plus 9 mid band channels (A through I). In this case there are 2,137 in band third order distortion products of which 62 do not fall on carrier frequencies.

Our laboratory cross modulation test-set consists of a set of 12 "standard" channels generated using "up-converters" from conventional heterodyne signal processors. Eight mid-band channels (Channels B through I) have been added to the set using similar "up-converters". These up-converters are driven from a crystal controlled IF source. The output frequencies of this 20 channel test signal source were measured recently as being representative of frequency range to be expected in a 20 channel head end using extensive signal frequency conversion and without special attention to oscillator stability, i.e. using local oscillators which are crystal controlled but not temperature compensated or temperature controlled. The expected "near" distortion products at 49.25 MHz were calculated and verified with the spectrum analyzer. There were 42 such products, compared with 18 in the 12 channel case. They ranged in frequency from 40.23698 MHz to 49.26973 MHz, a range of 32.75 KHz.

PROPOSED REMEDIES

It is obvious that the clustering of distrotion products would be eliminated if all the visual carriers were separted by exactly the same frequency. Since channels 4 and 5 are separated by 4 MHz instead of the usual 6 MHz we must drop the channel 4-5 spacing from the present discussion. If all the other channels are separated by exactly the same spacing the third order "near" distortion products will fall directly on a visual carrier instead of close to it. The interfering products would be "zero beat" and would slightly increase or decrease the carrier level according to their relative phase. The modulation side bands associated with each interfering carrier would still be present but it is suggested that this would manifest itself as a slight increase in cross modulation and that this effect would be less objectionable that the quality degradation due to the present clustering of interfering beats around each visual carrier. Simons noted that a triple beat in a 12 channel system would be expected to be about 21 db below the cross-modulation level. If 20 additional third order products resembling cross modulation were added we might expect the level of these products to rise about 16 db above the expected triple beat level. This would still put them about 5 db below the cross modulation level already present and would therefore contribute very little additional cross modulation. This interpretation is still speculative and experiments are now underway.

It is proposed that cable television head ends be designed so that the three major groups of adjacent channels be spaced individually by the same amount, i.e. that the spacing between adjacent channels should be locked to a master 6 MHz spacing oscillator. Phase locking techniques now make such a head end quite practical. Heterodyne processors capable of locking the output visual carrier frequency to an external frequency reference will soon be available and could be employed in the construction of such a head end. The principle can of course be extended to mid-band and super-band channels. Additional channels above and below the regular high band should be contiguous and use the same master spacing oscillator. Some channels may of course be omitted so long as the spacing between channels is eith 6 MHz or a multiple of the master 6 MHz oscillator.

This will cause most in-band third order modulation products to fall directly on visual carriers with consequent elimination of visible beats. Cross modulation will be increased somewhat. A few in-band third order products will still be present but these will be very few in number and not in sensitive portions of the channel. As the number of channels in a system rises about 12 it appears that intermodulation becomes the limiting system performance characteristic. A coherent head-end using common 6 MHz master oscillator spacing significantly reduces third order modulation and triple beat products. The exact value of this mode of operations will be determined from experiments within the next few months.

Several variations are possible to suit special local conditions. It may be desirable to lock one of the cable channels to a local broadcast channel. This is accomplished by making the local broadcast channel act as the reference frequency to whicha 6 MHz harmonic comb is added to produce the other reference frequencies. This may be extended to locking to two local channels by deriving the 6 MHz master oscillator from the difference between two local channels. Unless one of the local channels is channel 5 or 6 the difference between any two local channels will always be divisible by six and the required 6 MHz master frequency can be derived by digital division of the difference frequency between two local television carriers. If one of the local channels is 5 or 6 it can be locked to independently of the others. In such a case it would be possible to lock to three local carriers, one of them being channel 5 or 6.

A COMPLETE SYSTEM

It will be noted that the system of locking to a 6 MHz master spacing oscillator does not overcome second order distortion problems or triple sum or triple difference products. Beats involving the spacing between channels 4 and 5 are not handled either. A more complete remedy would be to use visual carrier frequencies which are harmonics of a master 6 MHz oscillator. In such a case all harmonic, sum, difference, and intermodulation products of all orders will be "zero beat". A head end for such a system can be effected in the way previously recommended, using phase-locking heterodyne processors and modulators, but the cable channels will not be receivable on ordinary television receivers because all channels (except 5 and 6) will have been lowered 1.25 MHz in frequency. Channels 5 and 6 will effective have been moved up by 0.75 MHz. Actually many receivers would be able to tune the new channel allocations (except new channel 6) because most fine tuners would have the tuning range to accommodate the new carrier allocation. Many receivers would, however, not tune the new carriers.

Many new systems are being built to handle more than twelve channels and are using tunable set-top converters in every installation. In some cases set top converters are being used to overcome local pick-up problems. In such cases the proposed harmonic carrier allocations could be used because it is just as easy to align a set-top converter to the proposed harmonic channels as to the present channels.

The required reference carriers would be generated by a master oscillator and harmonic generator.

Use of harmonically related visual carriers would cause second order products to "zero beat" but this does not completely eliminate their effect. The modulation sidebands associated with the mixing carriers also contribute to interference and the subjective effect of these sidebands is not yet known. It is expected that they would probably result in slightly increased cross modulation and that the overall effect would be an improvement over present operations. Systems with abnormally high second order distortion products might find that the resulting increased cross modulation would be excessive and might have to take additional steps to reduce second order distortion levels in their systems.

Hybrid systems which use harmonic carriers in a transportation trunk and regular carriers in local distribution can be considered. A multiple block converter can be designed that would shift harmonic carriers to regular channels in two blocks. Channels 2, 3, 4 and the high band would be one block and channels 5 and 6 would be the other block.

Some schemes for implementing augmented channel capacity require some of the channels to be "inverted", i.e. having visual carrier higher in frequency than the aural carrier. Such systems can be implemented with locked spacing or with harmonic carriers since this discussion of distortion products deals with only visual carrier spacing and frequencies. Associated aural carriers can be located above or below the visual carriers, as desired, so long as channels do not overlap in the transition between normal and inverted channels.

The reference carriers for a coherent head end can be generated in a number of ways. One practical way is to have a 6 MHz master oscillator drive a "comb generator" whose harmonic output comb is then mixed with a suitable base oscillator for each band of reference frequencies. All channel references can be based on a single base oscillator and 6 MHz comb, except for channels 5 and 6 whose base frequency must be offset by 4 MHz.

Channels normally processed by "on-channel" heterodyne processors will be shifted only slightly in frequency when locked to the coherent reference carriers. This requires careful shielding within the processor so that the input frequency, which is not coherent with the desired output frequencies should not leak through into the output, causing undesirable beats.

The accuracy and stability of the master 6 MHz oscillator and the base oscillators are not critical but should be chosen so that the final spectrum has accuracy and stability characteristics meeting applicable system specifications. Since +- 10 KHz accuracy is probably required at the highest channel, +- 5 KHz accuracy would be required in the base oscillator and the highest used harmonic of the master 6 MHz oscillator. This is approximately 5 KHz in 100 MHz in each oscillator so that .005% accuracy and stability should suffice.

THE CROSS MODULATION PROBLEM

1. Suppressed Carrier

The use of coherent harmonic carriers should practically eliminate problems associated with harmonics and intermodulation products. Actually the products are not eliminated but their subjective effect is drastically reduced. Cross modulation still remains and may indeed be effectively increased by the intermodulation between modulation sidebands.

A direct approach to the problem is to "unload" the amplifiers by suppressing the carriers. The system would operate as a double side band, suppressed carrier system. Actually a vestigial lower sideband system would still be used but the spectrum immediately around the carrier is double sideband and this is important in considering some of the problems associated with suppressed carrier. Benefits to be obtained may be estimated from consideration of RF envelopes for normal and suppressed carrier waveforms. Reduction of approximately 6 db in peak envelope are likely. This is a significant advantage since it effectively reduces amplifier outputs by about 6 db. This reduces second order products by 6 db and reduces third order products such as cross modulation and third order inter-modulation by 12 db. Alternately the additional 6 db margin can be used to improve signal to noise ratio by raising amplifier input levels appropriately. Unfortunately signal to noise ratio increases only 1 db for each 1 db increase in signal level, whereas cross modulation declines on a 2 for 1 basis. The 6 db improvement can "buy" 6 db of noise improvement of 12 db of cross modulation improvement. Operators would be able to take their choice.

Suppressed carrier channels are easy to generate using balanced modulators, but rather difficult to achieve through heterodyne processing of conventional TV carriers.

Re-insertion of the carrier for reception by conventional TV receivers is a difficult problem. A variety of techniques are available. The presence of both sidebands makes it important to achieve both correct frequency and phase for the re-inserted carrier. The presence of both sidebands also makes it possible to establish the carrier by squaring the DSBSC wave, filtering the component present at twice the carrier frequency and then electrically dividing this frequency by two (3).

Other carrier recovery systems are possible. One technique takes advantage of the special specular characteristics of television modulation. Envelope detection of a DSBSC television signal is not directly usable but is rich in horizontal scan frequency components. Envelope detection with an arbitrarily inserted carrier yields spectral components which can be compared with the H components from the detected DSBSC signal. A phase control sytem could adjust the re-inserted carrier to the proper position. (3)

Systems could probably be developed using carrier "bursts" during video sync pulses in a manner analogous to the transmission and detection of colour subcarrier in the NTSC colour system. Assuming a random phasing of sync pulses between channels in the system, the bursts of carrier should not significantly affect the overall system loading, since it would be unlikely that more than two or three such carrier bursts would occur simultaneously.

Suppressed carrier might make coherent carrier operation unnecessary, but the use of coherent carriers might make it easier to re-establish the carrier at the receiver terminal. Carriers could be re-established by resynthesizing from a pilot distributed in the system. A 6 MHz pilot tone could be multiplied into a spectrum comb which could then be mixed in with all the suppressed carrier channels simultaneously. Correct phasing would still be a problem but could probably be achieved.

It would be desirable if low cost carrier re-insertion could be achieved in a set-top converter. It is too early to judge the prospects for this kind of converter. We do expect to be using suppressed carrier techniques between major head ends in a large system within a year. This will allow us to test suppressed carrier effectiveness while working on the problems of low cost reception of DSBSC TV signals.

2. Coherent Video

TV carriers have maximum envelope amplitudes during sync pulses. Amplifier loading depends on the complex envelope representing the "sum" of the envelopes of multiple carriers. If the envelope peaks could be made to coincide on all channels maximum amplifier loading would occur at a known and controlled time, namely during picture blanking (horizontal and vertical) on _all_ channels. In between sync pulses the carrier envelopes would be significantly lower representing the envelope peaks reached by normal picture "blacks". Normal picture blacks would reach only about 66% of peak envelope. Peak envelope during picture content interval would therefore be about 3.6 db lower than during sync interval. NCTA specifications call for amplifier cross modulation measurements to be made with all video synchronous and measures the cross modulation from these synchronous video channels onto an unmodulated carrier. This is the worst case since all the channels except the one being measured have co-incident RF envelope peaks. Coherent video would make RF envelope peaks co-incident on all channels and the cross modulation resulting would come from RF envelopes corresponding to random picture content in all the channels. Cross modulation should be significantly reduced since the amount of cross modulation depends not only on the envelope peak but on the modulation index of the channels in the system. Most visible cross modulation arises from the blanking bars of other channels corresponding to their sync pulses. Since these aspects of cross modulation will never be visible, occuring during the vertical and horizontal blanking of the channel being watched, we may expect cross modulation reductions corresponding at least to the difference in modulation level between sync tips and normal picture blacks, about 3.6 db.

Coherent video can be achieved but at great economic cost. The problem is really phase coherence rather than frequency coherence. Virtually all TV stations today use colour sync generators with high quality colour subcarrier oscillators as the basic frequency standard. Normal tolerance is +- 10 Hz in 3.58 MHz equal to about 3 parts in 100 accuracy. Most sync generators are better than this. The relative phase of sync pulses will be quite arbitrary depending on transmission routes and distances and the phase in which a picture source happens to start. Phase and frequency can be adjusted by the use of "time base correction". Time base correction is used in quality video tape recorders and "black boxes" for general purpose time base correction are just now becoming available. Such correctors now achieve an "H lock", i.e. they lock the horizontal sync rate of two video sources. "V lock" can be achieved in video tape machines but is more difficult to achieve in a general purpose "black box" since it would require the ability to shift + or - ½ field, a rather long time span, compared to the half H line shifts required for arbitrary H lock. At the moment it appears that time base correction to permit "coherent video" is too expensive to contemplate in CATV systems. We are, however, watching developments in the video time base correction field with a view to possible implementation at a future date.

EFFECT ON CONVERTER DESIGNS

The use of coherent carriers which are harmonics of a master 6 MHz oscillator makes possible the consideration of some interesting converter and tuner designs.

The problem of image rejection and local oscillator radiation has forced converter designers to abandon the commonly used IF of 45.75 MHz in favour of substantially higher IF and local oscillator frequencies. IF frequencies are now often about 400 MHz and local oscillator frequencies are about 500 - 700 MHz.

It is difficult to make selective IF's at these frequencies and the potential usefulness of the converter as a "preselector" for TV receivers which do not have enough preselection of their own is lost.

If we select an IF frequency which is also a harmonic of 6 MHz, our local oscillators can also be coherent harmonics of 6 MHz. Any local oscillator leakage back into the system will be zero beat with system carriers. Since the local oscillator is not modulated it will not significantly affect the system carriers. An IF frequency of 42 MHz could be chosen for the visual IF. The local oscillator could be generated from a master 6 MHz pilot carrier transmitted through the system. Phase lock loops could lock the IF to a master 42 MHz reference or synthesizer techniques could be used to generate the required local oscillator frequencies. Imgae rejection would have to be controlled by appropriate RF selectivity. Images would be also be coherent and the system would probably be less sensitive to image interference for this reason. Use of a relatively low IF frequency with stable local oscillators would permit building adjacent channel selectivity into the converter. Surface wave filter technology is now being developed for use in TV IF's at 45.75 MHz. It is likely that these techniques will be adaptable to a 42 MHz IF, making low cost, very stable IF sections.

The desirability of a suppressed carrier system has been suggested and there will be efforts to combine all these techniques into a single, high performance, reasonably priced converter.

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1. K.A. Simons. "The Decibel Relationships Between Amplifier Distrtion Products', Proc. of the I.E.E.E., Vol 58, No.7, July 1970, p 1077ff
2. O. Muller, "Ultral-near UHF Power Transistors for CATV Applications", Proc. of the I.E.E.E., Vol. 58, No. 7, p 1112 ff.
3. Bell Telephone Laboratories; "Transmission Systems for Communications", 4th edition, p 103.

SUBSCRIBER TERMINAL INTERFACE REQUIREMENTS

T. P. Ellsworth
The Magnavox Company
Ft. Wayne, Indiana

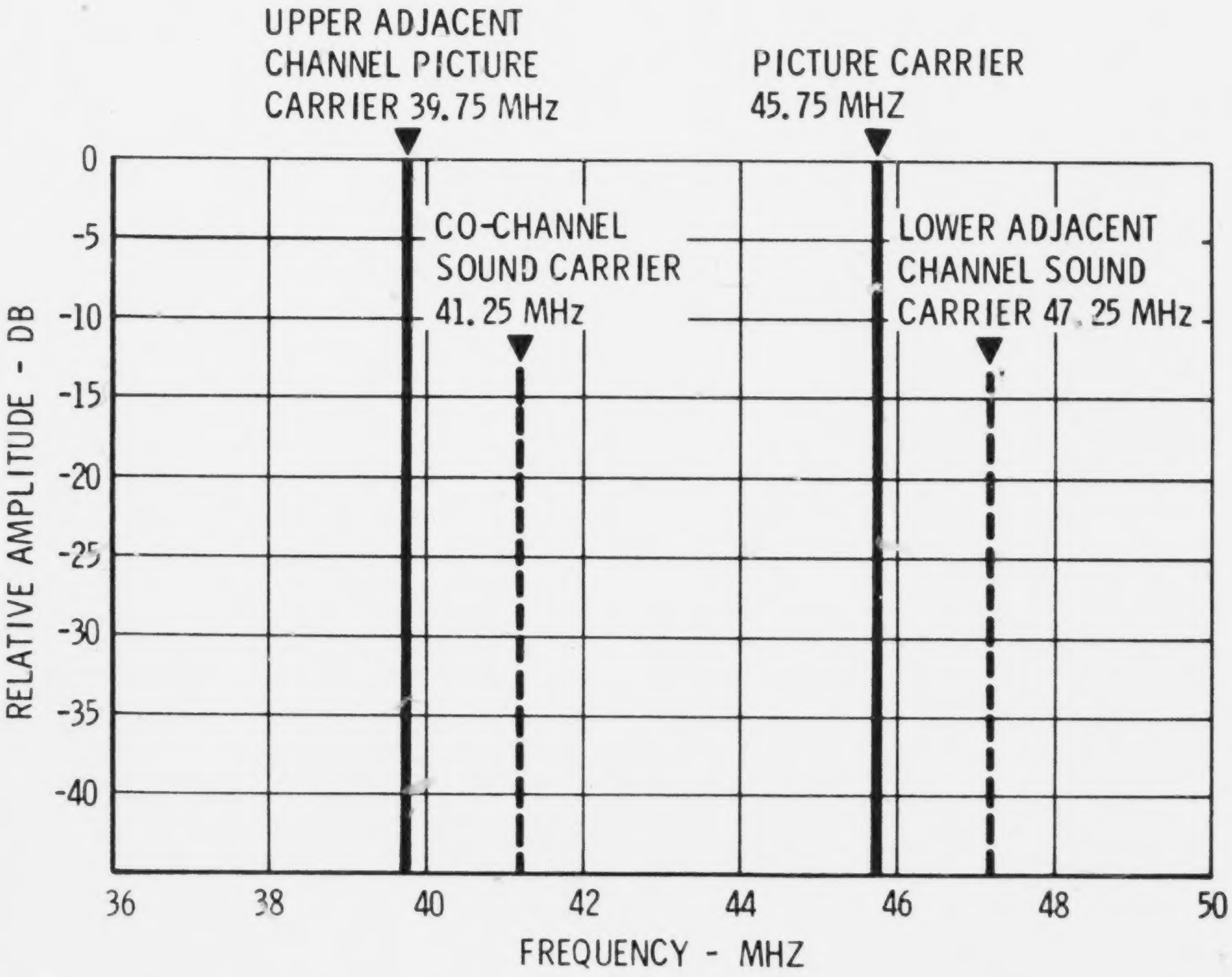
It is a privilege to serve with Dr. Powers and other members of the Frequency Allocation Subcommittee of the IEEE Coordinating Committee for Cable Communications Systems. I believe that the work of this group will prove to be significant in the development of needed frequency allocation standards for the cable television industry. During the course of our committee work, it became clear that performance characteristics of domestic television receivers are a major factor that must be carefully considered in establishing recommendations for frequency allocation plans. Time will not permit detailed consideration of all performance parameters that affect satisfactory operation of domestic color and monochrome receivers on Cable TV systems. I have selected four major topics for review in this paper:

(1) Rejection Ratios for Unwanted Adjacent Channels Carriers
(2) Local Oscillator Stability
(3) Local Oscillator Interference
(4) Receiver Noise Figure and Dynamic Range

These topics were selected because many of the reported difficulties with some models of television receivers operating on cable systems appear to be related to these four items.

Operation of conventional television receivers on "fully loaded" 12 channel cable systems requires some receiver performance characteristics that exceed the demands imposed by reception of a few non-adjacent over-the-air VHF channels. I cannot speak for the entire television receiver industry, but I do know that current production standards of

FIGURE 1 - ADJACENT CHANNEL VIDEO AND SOUND CARRIERS



VA4304

Magnavox television receivers embody the necessary design parameters and manufacturing controls to assure satisfactory television receiver operation on 12 channel cable systems. The design and manufacture of television receivers for satisfactory operation on 20 or more channels presents a set of new problems and new challenges.

Figure 1 illustrates the type of problem encountered by operation on contiguous, 6 MHz - spaced channels. The abscissa is shown in terms of TV intermediate frequencies. The adjacent channel picture and sound carriers are spaced only 1.5 MHz from the desired channel picture and sound carriers.

LOWER ADJACENT SOUND CARRIER

In Archer Taylor's report to the FCC for NCTA, "Performance Characteristics of Television Receivers Connected to Cable Television Systems," he suggested minimum threshold interference ratios between 35 and 40 db for suppression of lower adjacent channel sound carrier interference. Based upon a difference of 13 db between picture and sound carrier levels, and a difference of 3 db between adjacent channel video carriers, a selectivity ratio about 30 db would be required as a minimum to avoid interference from the lower adjacent sound carrier.

The 1950 tests referenced by Archer Taylor in the above report were probably conducted by observation of small screen monochrome receivers without aluminized picture tubes. We have conducted similar controlled interference tests, using large screen color TV receivers. We have verified the generally accepted minimum tolerable interference ratio of -57 db for coherent interference from signals in the vicinity of the video carrier. Thus, the adjacent channel sound carrier level at the second detector should not exceed 47 db:

57 db	interference ratio
-13 db	sound modulation level
+ 3 db	limit on adjacent channel signal level variance
-47 db	required rejection ratio for (47.25 MHz) adjacent channel sound carrier

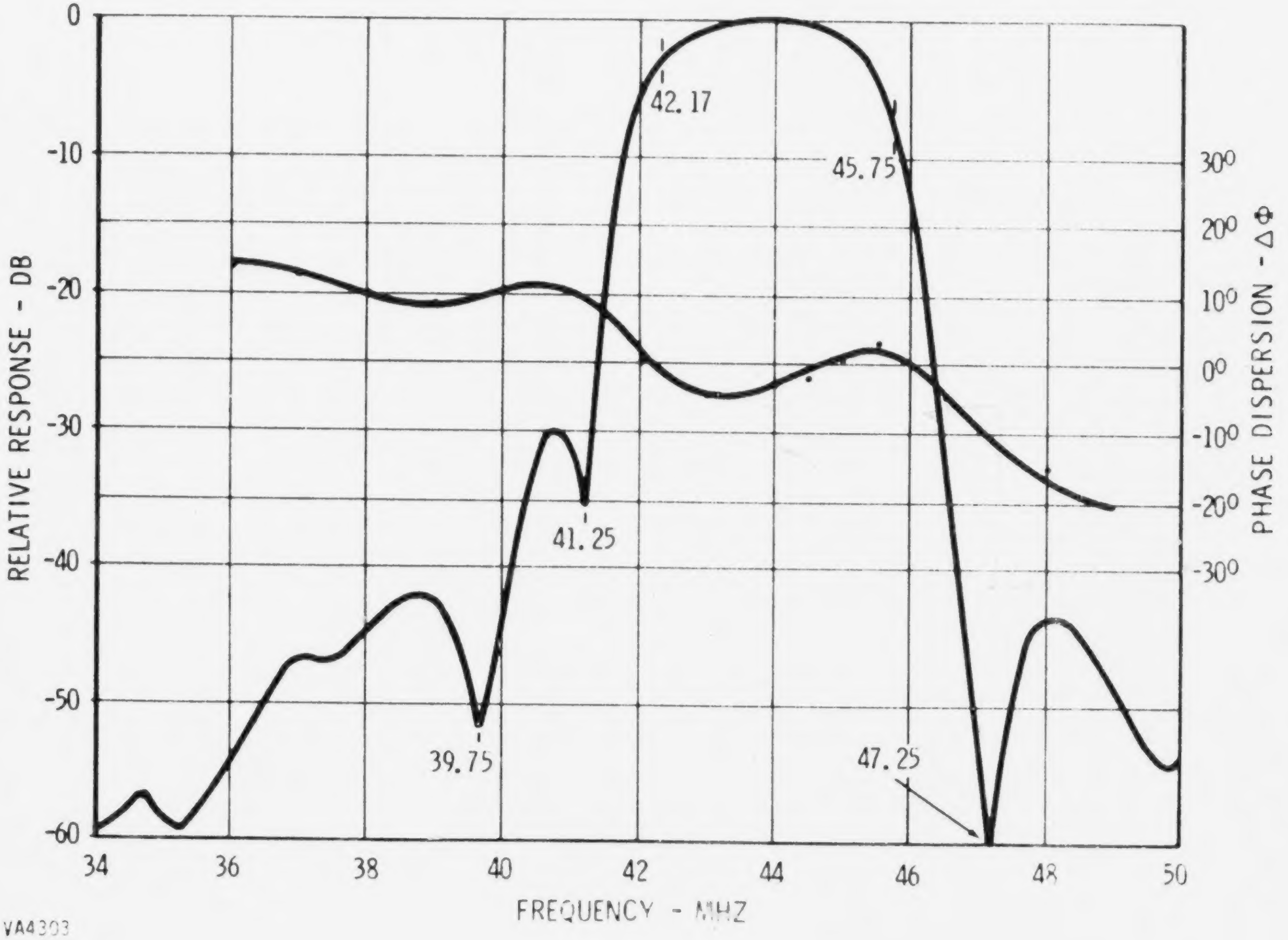
The rejection of the unwanted 47.25 MHz sound carrier is usually provided by a trap in the intermediate frequency amplifier, since the unwanted sound carrier is only 1.5 Mz from the co-channel picture carrier. Typical adjacent channel sound carrier rejection ratios of 60 db are provided by current television receivers manufactured by Magnavox. Rejection ratios exceeding 50 db for lower adjacent sound carriers were indicated on the tests reported by Archer Taylor. Thus, properly adjusted 47.25 MHz traps should provide adequate rejection of the upper adjacent sound carrier, providing the tuner is properly adjusted.

UPPER ADJACENT CHANNEL PICTURE CARRIER

Now, let us consider the effects of interference from the upper adjacent channel picture carrier. In order to avoid visible interference from the upper adjacent channel picture carrier, 40 db rejection of the unwanted adjacent picture carrier is required. The required rejection of the unwanted 39.75 MHz picture carrier is normally provided by a trap in an IF amplifier.

The effect of the upper adjacent 39.75 MHz carrier on the co-channel

FIGURE 2 - PERFORMANCE OF TV SOLID-STATE FILTER



sound carrier is reduced by 30 db rejection of AM interference provided by the FM limiter and sound detector. Thus, the total effective rejection of interference with co-channel sound at the output of the FM detector is the sum of the rejections provided by the i.f. trap and the sound limiter/detector, or 70 db.

Hence, the 40 db rejection of the upper adjacent picture carrier is adequate to handle interference with the wanted picture and sound carriers.

SOLID-STATE FILTER FOR TV IF AMPLIFIER

The required rejection ratios for the lower adjacent sound carrier and the upper adjacent picture carrier are now achieved by the use of lumped constant traps, whose satisfactory performance depends upon accurate adjustment. I would like to report progress in the development of a new type of solid-state filter, whose transfer characteristics are fixed by the intrinsic characteristics of the solid-state substrate, and never require adjustment.

The new solid-state filter has been developed in our Advanced Engineering Laboratories. This filter has performance characteristics that appear to satisfy all technical requirements for i.f. selectivity with a high degree of precision and stability. Reference is made to Figure 2, Performance of Solid-State Filter. The transfer characteristic of an experimental solid-state filter was tailored to the specific performance required for an i.f. transfer characteristic. It should be noted that the minimum 40 db rejection of the upper adjacent channel

39.75 MHz picture carrier is exceeded by a 12 db margin. Rejection of the lower adjacent channel sound carrier exceeds the calculated 47 db requirement by a 13 db margin. Thus, the lower adjacent sound carrier and upper adjacent picture carriers should have more than adequate suppression, even with minor inaccuracies in fine tuning and local oscillator drift.

Figure 3 lists the general performance characteristics of the solid-state filter. The transfer characteristics and filter rejection nodes for upper and lower adjacent channel carriers are established in a highly precise manner in the replication process, and no individual adjustments are required. The filter characteristics have crystal stability, and will not drift significantly with age. The filters also have excellent temperature stability over normal temperature operating range - ± 20 KHz for a temperature range -5° to +75°C.

During the technical sessions of the Frequency Allocation Subcommittee, a proposal was made to provide a "guard band" of 1/4 to 1/2 MHz between cable channels in order to solve the reported adjacent channel interference problem. I did not recommend adoption of this proposal, because of the consequent lost transmission bandwidth, and because it is possible to achieve adequate performance with our present lumped-constant circuits. The introduction of the solid-state filter will facilitate uniform and stable performance in future commercial television receivers.

FIGURE 3 -

PERFORMANCE FEATURES OF SOLID-STATE FILTERS

1. FREQUENCY RANGE - 10 MHz TO 1 GHz
2. PHASE LINEARITY - $< 5^0$ DEVIATION THROUGHOUT FILTER PASSBAND
3. DYNAMIC RANGE - >90 dB
4. NUMBER OF ADJUSTMENTS - ZERO
5. MISALIGNMENT DUE TO SHOCK, VIBRATION, AND AGING - $<\pm 400$ Hz AT 40 MHz
   (CRYSTAL STABILITY)
6. TEMPERATURE STABILITY - $<\pm 20$ kHz OVER -5^0 TO $+75^0$C RANGE
   (40 MHz CENTER FREQUENCY)
7. BW OF NOTCHES (TRAP FILTER) - >50 kHz (6-dB POINTS)
8. DEPTH OF NOTCHES (TRAP FILTER) - >50 dB OVER 50 kHz BW
9. INTERFACING - COMPATIBLE WITH IC'S AND TRANSISTORS

VA4302

APPLICATION TO COLOR TELEVISION RECEIVERS

The same design and process techniques that were used to develop the solid-state filter are also applicable to automatic frequency control circuits. Figure 4 is a block diagram of the radio-frequency and intermediate frequency amplifier sections of an experimental television receiver. In this design, the automatic frequency control circuit is controlled by the solid-state circuit elements fabricated on the same substrate as the solid-state trap filter. In this configuration, any minor thermal drifts in the local oscillator frequency and trap null points due to substrate characteristics will track, and rejection of unwanted carriers will be maintained.

LOCAL OSCILLATOR STABILITY

Now, let us consider the stability of the local oscillator. The magnitude of local oscillator drift depends upon a number of factors, including:

Magnitude of thermal rise of tuner environment

Shift in electrical characteristics of passive circuit tuning elements as a function of ambient temperatures

Type of active devices used in oscillator circuit, and their susceptibility to thermal rise

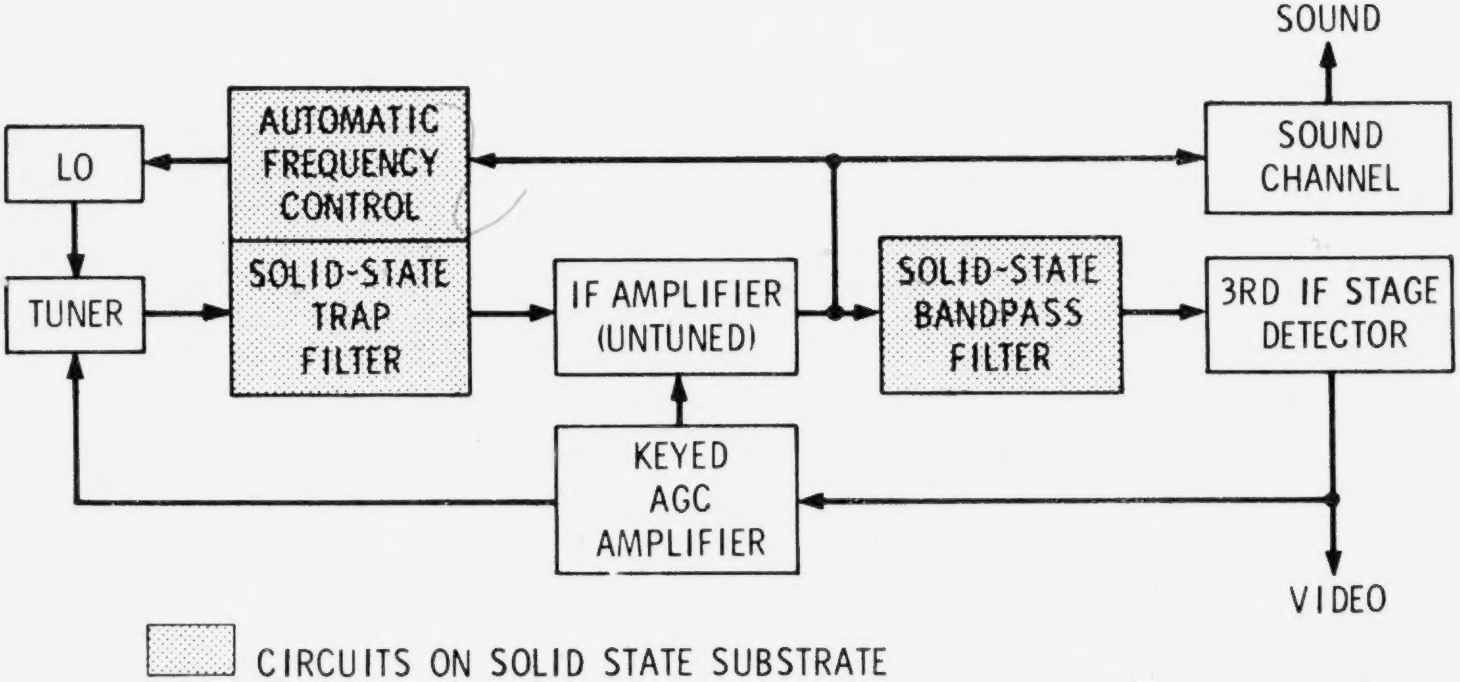
Control range and control ratio of AFC circuits, and thermal stability of AFC circuits

Susceptibility of oscillator circuits to power supply voltage changes

A wide variety of types of VHF tuners are in current use, with a correspondingly wide variety in the magnitudes of local oscillator

FIGURE 4 -

BLOCK DIAGRAM OF TV RF AND IF SECTION
(SHOWING SOLID-STATE FILTERING ELEMENTS)


SOUND
AUTOMATIC FREQUENCY CONTROL
LO
SOUND CHANNEL
SOLID-STATE TRAP FILTER
TUNER
IF AMPLIFIER (UNTUNED)
SOLID-STATE BANDPASS FILTER
3RD IF STAGE DETECTOR
KEYED AGC AMPLIFIER
VIDEO
▨ CIRCUITS ON SOLID STATE SUBSTRATE

drift over several hours. The tests reported by Archer Taylor indicated local oscillator drifts from 65 KHz to 200 KHz in one hour. Industry sources have suggested that an acceptable high limit for long term thermal drift for current VHF tuners should be +100 KHz, -300 KHz, without AFC correction; frequency shifts due to line voltage changes would be ±100 KHz. The above values for thermal drift seem to be higher than our experience with current VHF tuners. The specified drift for a typical tuner is: For a 15°C thermal rise, the long-term local oscillator drift limit is 75 KHz, without AFC control. Using an AFC loop with a 10:1 control ratio, the total long-term thermal drift is less than ±10 KHz.

Changes in local oscillator frequency due to line voltage changes could be significantly reduced by the use of a voltage regulator for the VHF tuner.

On the basis of the information available, it appears that thermal drift of TV local oscillators can be controlled within tolerable limits, by proper application of known design techniques, considering the design parameters listed above.

The combination of precisely-controlled and stable filter nodes in the solid-state filter and AFC - controlled thermal drift of the local oscillator, the adjacent channel sound and picture carriers should produce no discernable adjacent channel interference.

LOCAL OSCILLATOR INTERFERENCE

Let us consider the effects of local oscillator signals conducted to the cable.

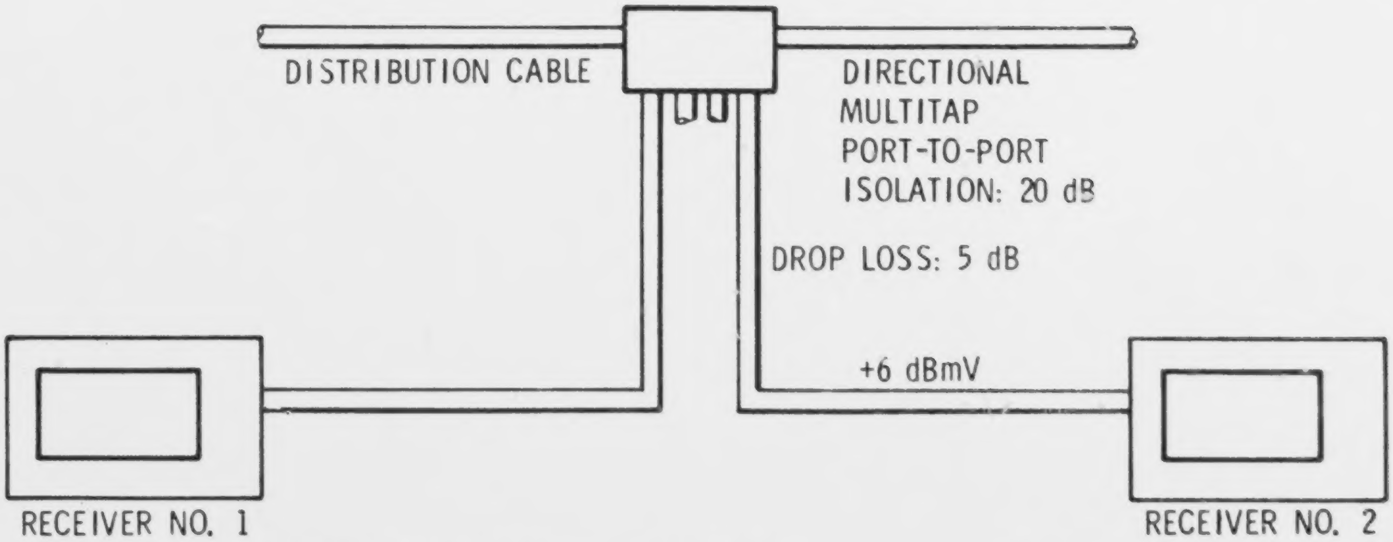
A variable local oscillator in a television receiver is mixed with a received signal to generate the intermediate frequency. Since the mixer circuit is not electrically isolated from the cable, the local oscillator fundamental and harmonics can be readily conducted to adjacent subscribers. The standard 12 VHF channels were assigned in such a way that the local oscillator fundamental frequencies do not interfere with the VHF channels. However, the local oscillator signals and their harmonics can cause interference with mid and super band channels.

Figure 5 illustrates how the local oscillator signal from Receiver No. 1 is conducted to Receiver No. 2 via the subscriber drops and directional multitap. If the maximum allowable level of coherent interference is -57 db, and the cable TV signal level is +6 dbmv, the maximum allowable received local oscillator interference level at Receiver No. 2 is -51 dbmv. If 5 db cable drop loss is assumed for each subscriber, and the tap port-to-port isolation is 20 db, the maximum allowable L.O. signal level generated at the terminal of Receiver No. 1 is -21 dbmv, or 80 uv. This value is similar to the 100 uv limitation of local oscillator signal level requested in the NCTA petition to the FCC.

Measurements of local oscillator signal levels and harmonics at the 75 ohm terminals of current VHF tuners indicate that the 100 uv level limitation could be satisfied by some tuners, but not by others.

FIGURE 5 -

LOCAL OSCILLATOR INTERFERENCE LEVELS


DISTRIBUTION CABLE
DIRECTIONAL
MULTITAP
PORT-TO-PORT
ISOLATION: 20 dB
DROP LOSS: 5 dB
+6 dBmV
RECEIVER NO. 1
RECEIVER NO. 2

ALLOWABLE COHERENT INTERFERENCE:	-57 dB
CATV SIGNAL LEVEL AT RECEIVER:	+ 6 dBmV
MAXIMUM ALLOWABLE L.O. INTERFERENCE LEVEL	-51 dBmV
DROP LOSS BETWEEN RECEIVERS	10 dB
PORT-TO-PORT ISOLATION:	-20 dB
ALLOWABLE L.O. SIGNAL LEVEL	-21 dBmV, or 80 UV

VA4305

Based upon a design study conducted by a tuner manufacturer, it was determined that the proposed 100 uv limitation on local oscillator signal level can be achieved by the use of shielding and traps, at some additional cost. Adoption of the 100 uv limit would control only one part of the problem -- new television receivers. However, the interference produced by existing receivers in systems with more than 12 channels will be a continuing problem.

RECEIVER NOISE FIGURE AND DYNAMIC RANGE

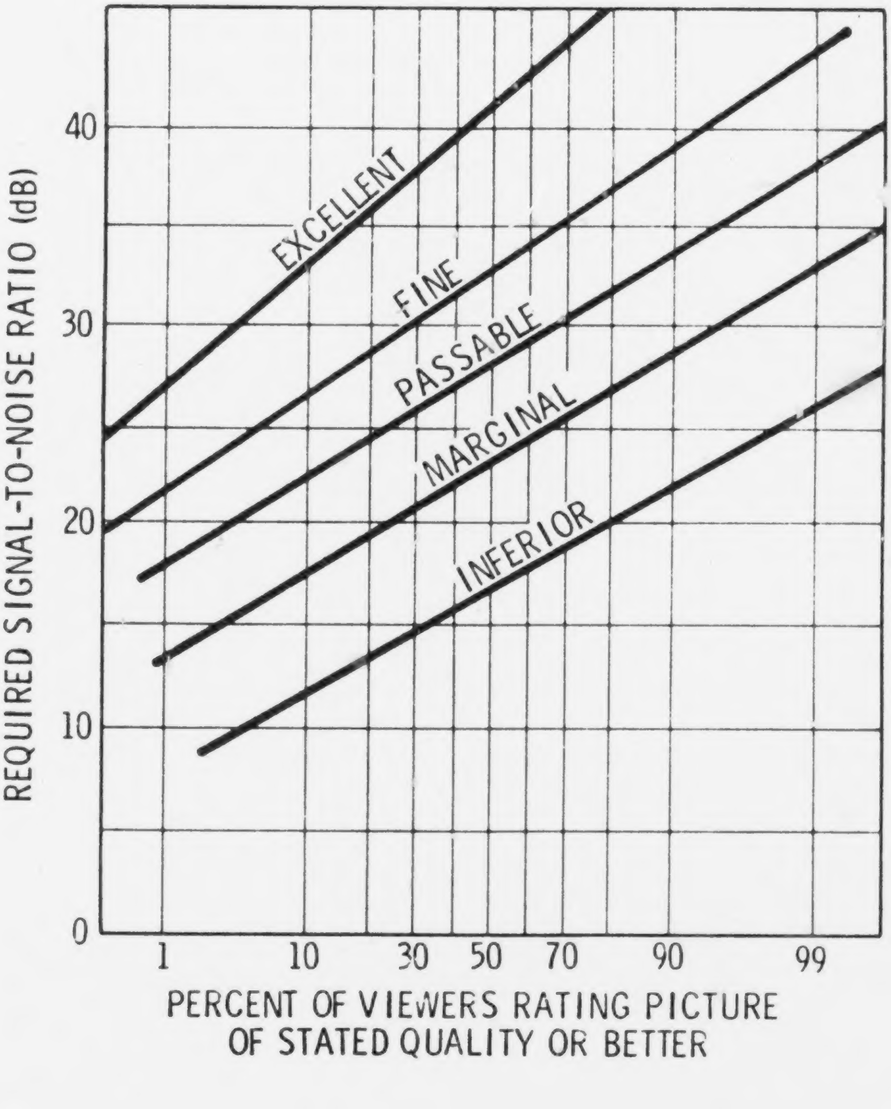
Let us now review limitations imposed by receiver noise level and cross modulation level on overall receiver performance.

During the past several years, technical progress in the design of input circuits for television tuners has resulted in improvements in noise figure. Ten years ago, noise figures in the range 10-12 db were considered representative for VHF tuners. Today, noise figures in the 5-6 db range are considered representative.

The tolerable level of noise present at the picture tube can be expressed as the db ratio of video signal power to noise power. Various tests of the tolerable level of $(S/N)_{picture}$ have been conducted. Figure 6 presents the results of the TASO panel 6 tests: from this figure, a $(S/N)_{picture} = 40$ db results in "fine" picture quality for a large percentage of the observers participating in the TASO tests.

It can be shown that, for a "noisy" video source, the signal level delivered to the input terminals of the cable subscriber's receiver

FIGURE 6 - **TV PICTURE QUALITY, TASO PANEL 6 DATA**



must be higher than would be the case for a noise-free video source and a noise-free receiver. As shown in Figure 7, mathematically, the relationships between signal, power (P_{signal}), receiver noise power (P_N) receiver and the overall signal to noise ratio of a noisy video source $(S/N)_{Video\ Carrier}$ are:

$$(S/N)_{Picture} = \frac{P_{Cable\ Signal}}{P_{Noise,\ Receiver} + \frac{P_{Cable\ Signal}}{(S/N)_{Video\ Carrier}}}$$

Figure 8 presents the results of a computer run of computed input levels required at the receiver to achieve $(S/N)_{picture}$ = 40 db as a function of $(S/N)_{Video\ Signal}$ ratios 38 to 50 db, and for tuner noise figures of 5 db and 12 db. The Video Carrier (S/N) Ratio includes all sources of noise in video signal generation, as well as noise added by the cable distribution system. In order to achieve a $(S/N)_{picture}$ = 40 db, the video carrier S/N ratio at the input to the receiver must be greater than 40 db, and must be delivered at a level appreciably greater than just 40 db above the equivalent receiver noise.

Examination of the curves show that, for a $(S/N)_{Video\ Carrier}$ = 44 db, a tuner with 12 db Noise Figure would require a cable signal level of -12 dbmv. It should be noted that the required signal level to maintain a $(S/N)_{Picture}$ = 40 db increases quite rapidly as $(S/N)_{Video\ Carrier}$ is reduced. For example, a tuner with 12 db noise figure would require 0 dbmv signal level for $(S/N)_{Video\ Carrier}$ = 41 db.

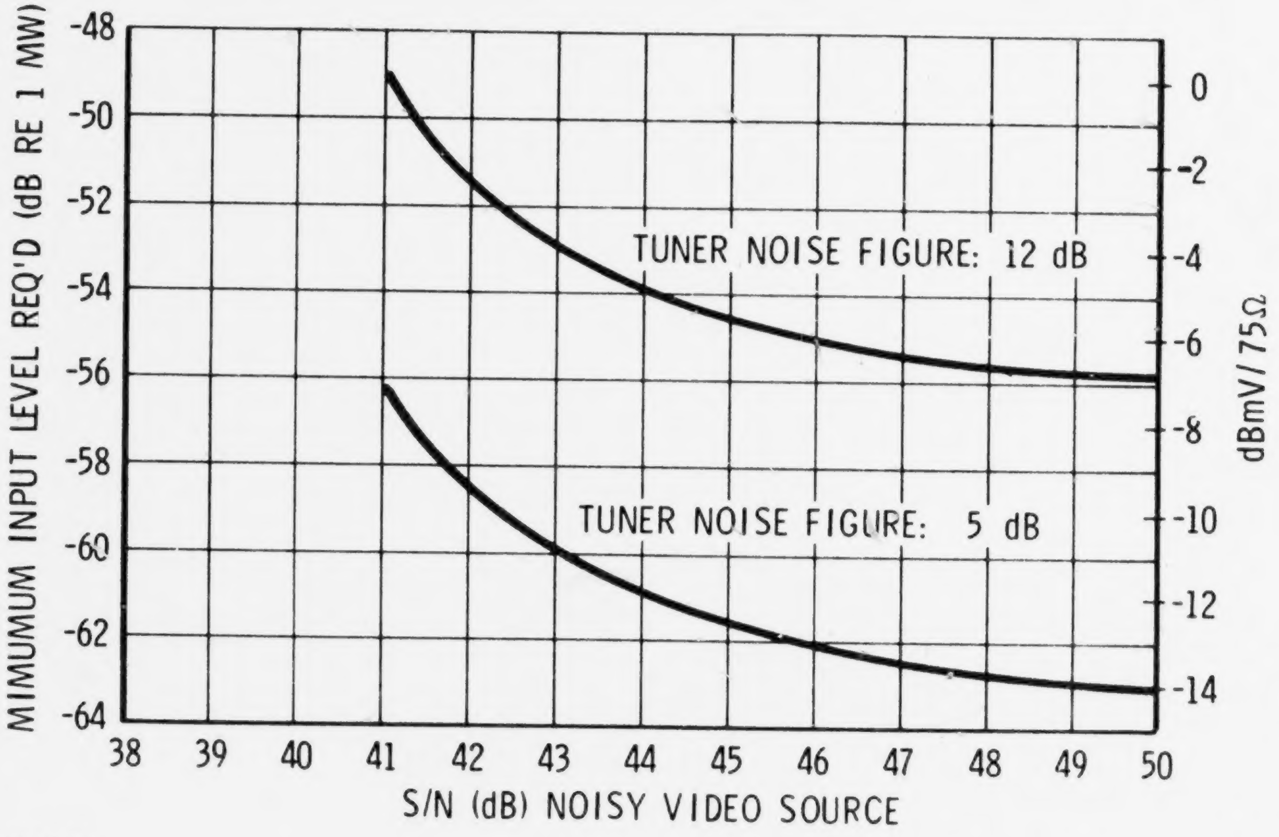
FIGURE 7 - **RELATIONSHIP OF S/N RATIO OF VIDEO SOURCE ON REQUIRED CABLE SIGNAL POWER LEVEL FOR AN ACCEPTABLE TV PICTURE S/N RATIO**

$$(S/N)_{\text{PICTURE}} = \frac{P_{\text{CABLE SIGNAL}}}{P_{\text{NOISE, RECEIVER}} + \dfrac{P_{\text{CABLE SIGNAL}}}{(S/N)^{*}_{\text{VIDEO SIGNAL}}}}$$

* INCLUDES ALL SOURCES OF NOISE PRESENT IN CABLE VIDEO SIGNAL

VA4306

FIGURE 8 - **INPUT SIGNAL LEVEL REQUIRED FOR 40 DB PICTURE QUALITY vs. S/N RATIO, NOISY VIDEO SOURCE**



VA4307

Thus, the performance of modern television receivers does not appear to be receiver noise limited. The FCC requirement of 0 dbmv minimum signal level should provide adequate service to cable subscribers.

A series of tests was conducted to determine the performance of Magnavox teleivision receivers with respect to cross modulation at high signal levels. The tests utilized 26 cable channels operating at equal levels. Several types of tuners were evaluated; both vacuum tube and solid-state tuners were tested. Signal levels were varied from 0 dbmv to +20 dbmv in 2 db steps, and the resulting pictures were evaluated for evidence of cross modulation. Under these conditions, no observable cross modulation was detected at signal levels up to +20 dbmv. Since this signal level is well above normal signal levels delivered to cable subscribers, we concluded that the dynamic range of our current tuners is adequate for operation on 12 channel cable systems.

From the foregoing tests, we believe that no limitation in overall performance is imposed by receiver noise level for minimum level cable signals, nor by intermodulation distortion for high level cable signals.

CONCLUSION

In this paper, I have attempted to summarize progress that has been accomplished in solving some of the reported problems in operating television receivers on cable systems. I believe that further progress toward the goal of delivering the best possible service to television viewers, whether they be served by cable TV systems or by broadcast television, depends, to a high degree, upon industry-wide understanding of the problems involved, cooperation among concerned Government agencies, the CATV industry, and domestic television manufacturers. I believe that we are experiencing a good example of this type of understanding and cooperation in the work of the Frequency Allocation Subcommittee of the IEEE Coordinating Committee for Cable Communications Systems.

HIGHLIGHTS
TECHNICAL SESSION

CABLE SYSTEM OPERATION

Chairman

John Walson
Service Electric Co.
Mahanoy City, Pennsylvania

Speakers

Larry New
Cox Cable Communications Inc.
Atlanta, Georgia

Derald O. Cummings
C-COR Electronics Inc.
State College, Pennsylvania

Paul Robbins
National Society of Professional Engineers
Washington, D.C.

R. L. Douglas
Helwick Douglas Electronics Inc.
Gulfport, Mississippi

Steven I. Biro
B-RO Antenna & Head-End Engineering
Princeton, New Jersey

Reporter

Walter Wydro
Consulting Engineer
Pineville, Pennsylvania

Mr. Walson is an early CATV pioneer and he opened the session with a brief history of how CATV first started in Mahanoy City, Pennsylvania. As a television dealer, he demonstrated television sets to prospective purchasers. To this end, he erected a 70-foot pole with antennas on a high hill. From this beginning, he began distributing and later amplifying these weak signals with broadband boosters; and, thus, the form of CATV as we have it today had its humble beginning.

1. "A Documentation Process for CATV Systems" - Larry New

Mr. New stated that a system must mmet the following documentation criteria:

> Availability of accurate large-scale maps for construction. The scale must be large enough to locate amplifiers accurately.
>
> Smaller set of maps for use by maintenance and systems personnel.
>
> All maps must be capable of accepting changes and revisions.
>
> Must have originals to permit updating and also to make future addtional copies.

Special maps are used for construction and these are usually 24" x 36" and of a scale of 1" = 200. Larger maps are difficult to handle, and experience has shown that this is an optimum size. The next major map is the street and strand map showing poles, streets, crossings and schools, apartments or other unusual drops.

The 24" x 36" maps are reduced 50% for the working maps. This master is a "blue line" nylon original and allows the working prints to be able to be economically made. These reduced maps are placed in heavy, clear plastic to increase wearability. Total cost of one set of approximately forty maps for a 150-mile typical system is $263; each duplicate set costs a total of only $2.50. At this low cost, every truck can be equipped with a complete set of maps, thereby facilitating system maintenance.

2. "Considerations for Transient and Surge Protection in CATV Systems" - Derald O. Cummings

Power system surges are one of the main causes of surge voltages in CATV systems.

A lightning stroke has typically: one to 10 microseconds rise time and 100 microseconds exponential decay and are also characterized by very high peak currents.

Surge voltages can be of either polarity. Most of the energy is low frequency, but the high peak current results in appreciable energy for frequencies of 16 MHz and higher. The resistance to ground or earth must be as low as possible. A one ohm ground resistance can have 20 kV developed under typical conditions. System grounding is important and multiple bonds help considerably. Because CATV aerial systems have pole lines, the upper lines take the brunt of lightning surges.

Fast-acting voltage limiters should be used at the input ports to provide the greatest surge protection.

Some typical surge protection devices are:

Silicon P-N Junction Diodes (provide limited surge current)

High Power Gas-Filled Surge Suppressor (fast and has high peak currents capability)

Zenner Diodes (intermediate capacitance, fast switching, low-surge current capability)

Diac, Triac and SCR (moderate power dissipation)

Varistors (metal oxide devices with voltage variable resistance, high capacitance and fair peak current capability

Thyristors (silicon carbide devices similar to varistors)

Time Delay Power Relays (during power surge, will disconnect applied power)

3. "Can Cable System Management and Retreaded Aerospace Engineers Adapt to Each Other?" - Paul Robbins

Mr. Robbins presented his intriguing views on the adaptation of Aerospace Engineers to CATV. With a forecast of some twenty-five to thirty million total subscribers by 1980, the cable industry will not be able to develop adequately unless there is a sufficient pool of engineering and technical manpower available.

4. "Field Strength Monitors, A Unique Test Instrument for CATV" - R. L. Douglas

This novel approach combines the functions of a field strength meter, a television monitor, and a video display in one portable instrument. This instrument provides the capability to observe any interference in the video or audio TV signals while measuring the amplitude or strength of these signals. This versatile instrument can be used in the lab to calibrate front-end equipment; in the field to adjust line amplifiers; and in the home to demonstrate the quality of CATV signals.

5. "Antenna Site & Head-End Selection Problems in Big City CATV Systems" - Steven I. Biro

Mr. Biro discussed the problems peculiar to large city head end sites. He indicated the care needed to properly determine the suitability of a site for a large city reception point. Ghosting and interference are the two greatest problems facing large city reception locations. He explained how ghosts are developed and cited methods to determine the source of the reflection.

Finally, Mr. Biro gave a means of examining the spectrum to determine the source and direction of interfering signals in those cases where this kind of problem is encountered.

A DOCUMENTATION PROCESS FOR CATV SYSTEMS

LARRY D. NEW
COX CABLE COMMUNICATIONS, INC.

Today's CATV systems are complex networks of specialized electronic equipment and cable -- much too complex to be retained wholly in the minds of the personnel responsible for the system operation. A uniform system of documenting this information must be adopted in order to maintain a CATV system under the standards we operate with today.

To fulfill this requirement, any documentation system must meet the following criteria:

1. Accurate, large-scale maps are needed for proper system design and to ensure correct placement of cable and electronic equipment during construction.

2. Smaller scale, less cumbersome, more durable maps are needed for everyday field use by maintenance and installation personnel.

3. The maps must be readily adaptable to periodic changes and additions that occur once the system is in operation.

4. A permanent copy must be available in storage in the event of accidental loss of the maps in use.

5. The maps must be easily interpreted to prevent costly mistakes during construction and when in operation.

The following system developed by Cox Cable Communications meets all of the above criteria. It has been proven on the drawing board as well as in systems under construction and in operation.

Design and Construction Prints:

The maps used for system design and construction must be on a scale large enough for accurate measurement and ease of comprehension, but also of a size that can be easily handled by men in the field. A map on the scale of one inch to two hundred feet and a size of 24"x36" fulfills both these requirements.

These maps are drawn in ink on pre-cut, pre-printed mylar border sheets (Fig. 1). The use of ink naturally requires a certain amount of additional time, but the combination of ink and mylar produces a master print of a quality and durability that easily compensates for this.
Using a pre-printed border sheet saves time and allows the inclusion of a symbol key strip along with each map. A one-inch overlap beyond the match line on all four sides ensures continuity into all adjoining sheets. The small numbers at the intersection of the match lines indicate the adjoining map numbers. The bar type scale at the bottom was chosen to allow accurate measurement when the map is enlarged or reduced.

Street names, railroads, rivers, poles, strand, span measurements and any other pertinent information is included in these maps to produce the street and strand master map (Fig. 2). Inexpensive blue-line work sheets are printed from this master for use in designing the electronics layout. At this time, an erasable mylar sepia second master also is printed.

The electronics layout, having been completed in pencil on the blue-line work sheet, is now transferred in ink onto the mylar sepia which becomes the electronics master. The electronics was placed on the sepia rather than the original for an important reason. The life of the electronic equipment and cable is much less than that of the mylar original and the strand information shown there. At some point in time, the electronics and cable will be replaced and the existence of the strand master free of electronics will eliminate the need to redraw this portion of the maps.

When the electronic masters are completed, blue-line work prints of whatever number are needed can be run without damage to the masters.

Maintenance Prints:

As a system progresses from the construction phase into normal operation a different set of maps becomes necessary. The original 24"x36" blue-line work prints can be used for maintenance and installation work, but when used constantly from a service truck these maps are difficult to handle and their life expectancy is very short. Therefore, a smaller, more durable set of maps becomes very valuable.

These maps are made by photographically reducing the 24"x36" electronic masters by fifty percent and printing them back on either wash-off mylar or cronaflex. This produces a 12"x18" reduced electronic master (Fig. 4).

From these small masters any number of very inexpensive blue-line prints can be made. These prints are then placed in a rugged plastic binder (Fig. 5) which gives them a life span many times greater than unprotected prints. By using this method it is possible to supply each service and maintenance truck with a complete record of the entire system.

As a bi-product of making the 12"x18" reduced electronic masters, a second very valuable product is also produced. The negative which must be made to accomplish the high quality reduction can be stored in a vault or other secure storage area. In the event of fire or other accident, the negatives can be used to reproduce either the 24"x36" or the 12"x18" masters thus saving considerable time and expense.

Updating:

No matter how accurate or costly any documentation system may be, it becomes virtually worthless if it is not kept up to date. A regular program of periodic updating must be established and carried on. As mentioned previously, we made 24"x36" erasable mylar sepia electronic masters and 12"x18" wash-off or cronaflex reduced masters. These materials were chosen because they accept changes and additions very readily.

Since the trucks are now carrying the smaller size maps it is very inexpensive to remove and discard any sheets where changes have occured and replace them with new updated copies. By doing this, system personnel will always have an accurate set of maps readily available.

Cost:

The cost of producing a system such as this will vary dependent upon local reproduction cost, but the following figures should serve as a representative average:

24"x36"	Pre-printed Mylar Border Sheet	$1.29 each
24"x36"	Erasable Mylar Sepia	1.53 each
24"x36"	Blue-line Work Sheet	.19 each
12"x18"	Wash-off Mylar or Cronaflex Reduction	1.85 each
	Film Negative Used in Making Reduction	1.65 each
12"x18"	Blue-line Print	.02 each
	Custom Printed Plastic Binder for 12"x18" Prints	1.83 each

The total cost, excluding labor, of one complete set of 12"x18" maps, including binder, for an average system of 150 miles or 40 sheets is $263.03. This figure may appear high but the majority of the cost is in producing the first set. Each additional set will cost only $.02 per sheet for the 12"x18" blue-lines and $1.83 each for the protective plastic binders or a total of only $2.63.

This method of system documentation will provide the necessary maps for all phases of system operation, from construction on through daily maintenance acitivties.

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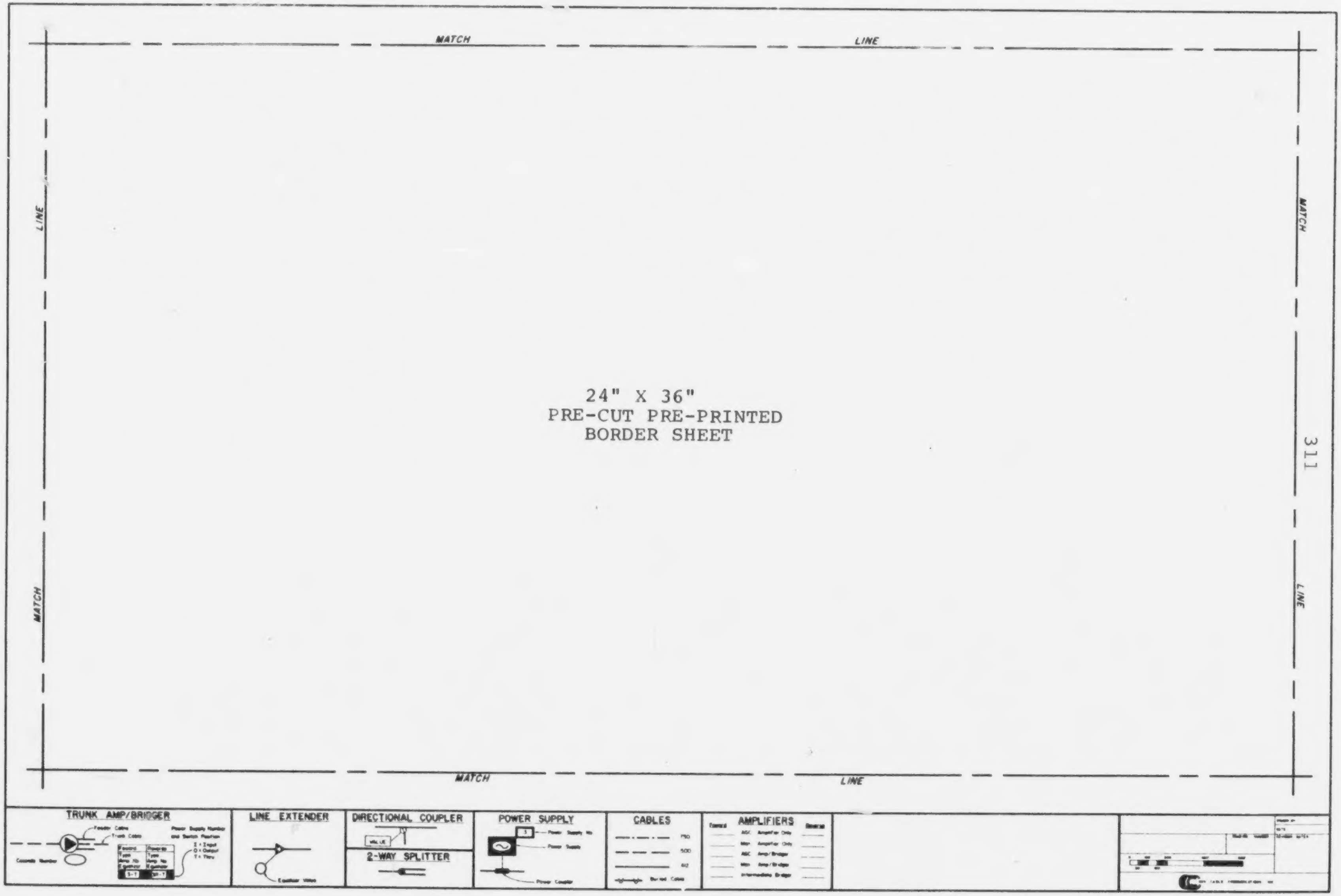
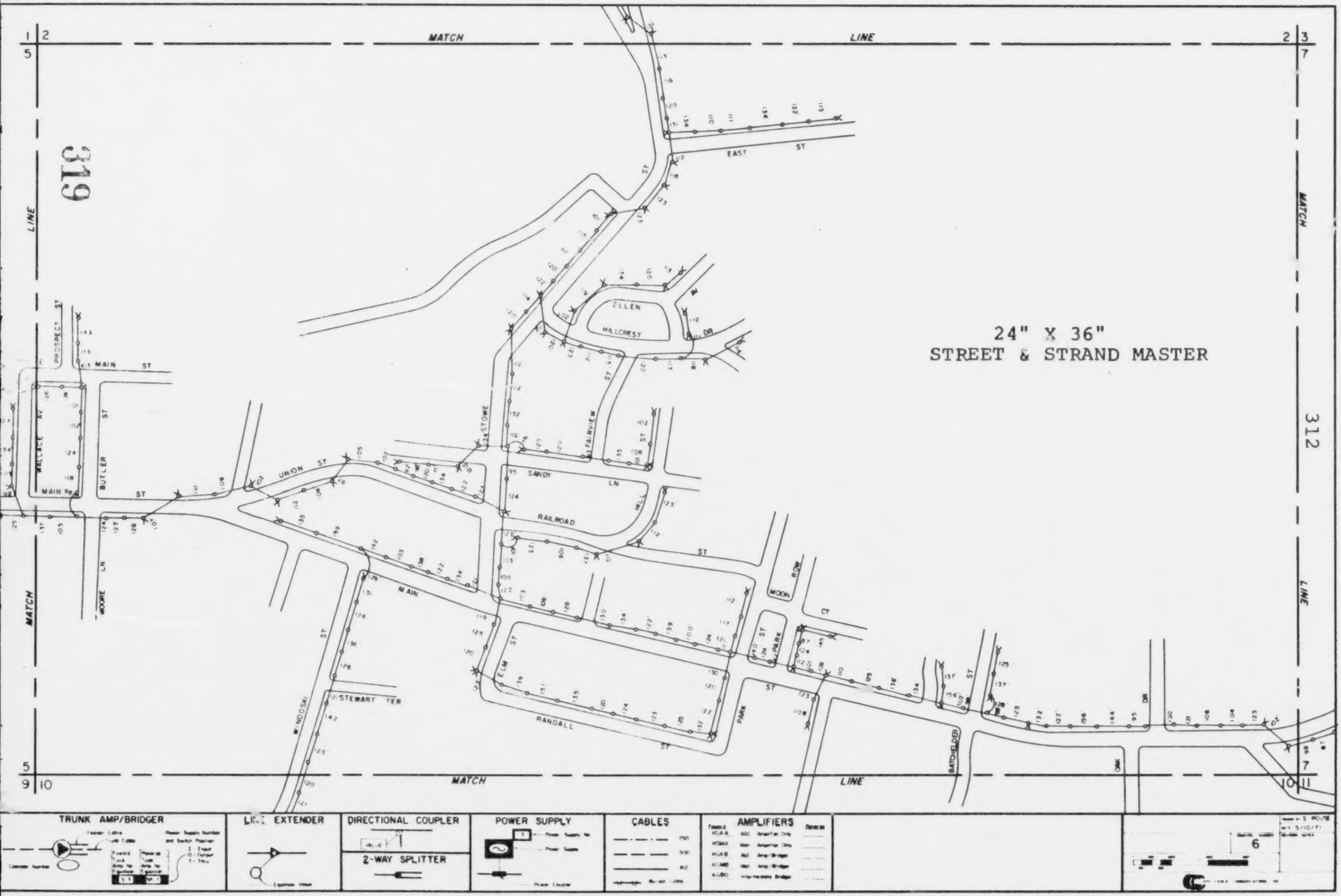
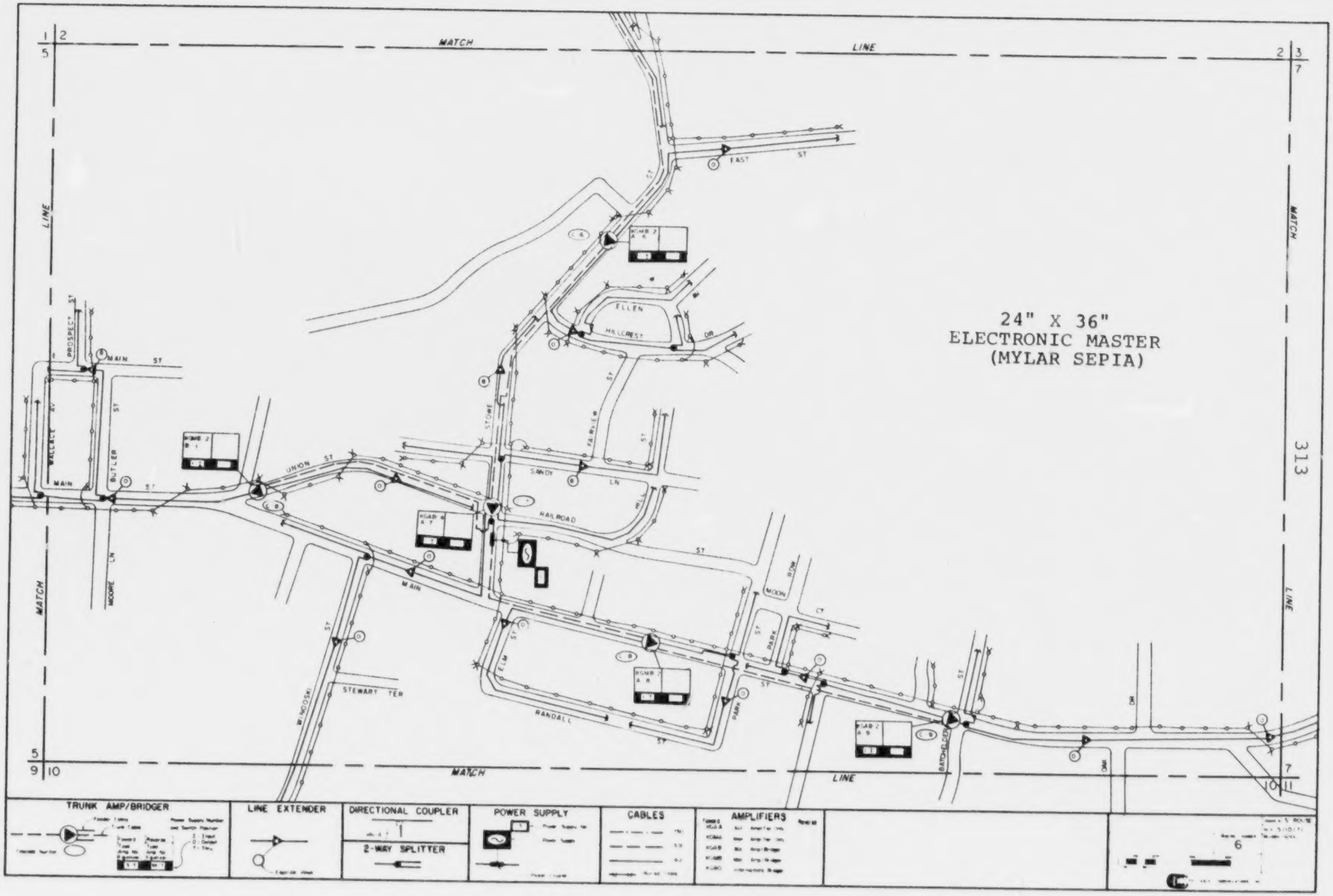

MATCH
LINE
24" X 36"
PRE-CUT PRE-PRINTED
BORDER SHEET
TRUNK AMP/BRIDGER
Feeder Cable
Trunk Cable
Power Supply Number and Switch Position
Cascade Number
Forward
Reverse
Type
Amp No
Equalizer
I = Input
O = Output
T = Thru
LINE EXTENDER
Equalizer Value
DIRECTIONAL COUPLER
VALUE
2-WAY SPLITTER
POWER SUPPLY
Power Supply No
Power Supply
Power Coupler
CABLES
750
500
412
Buried Cable
AMPLIFIERS
Forward
Reverse
AGC Amplifier Only
Man Amplifier Only
AGC Amp/Bridger
Man Amp/Bridger
Intermediate Bridger

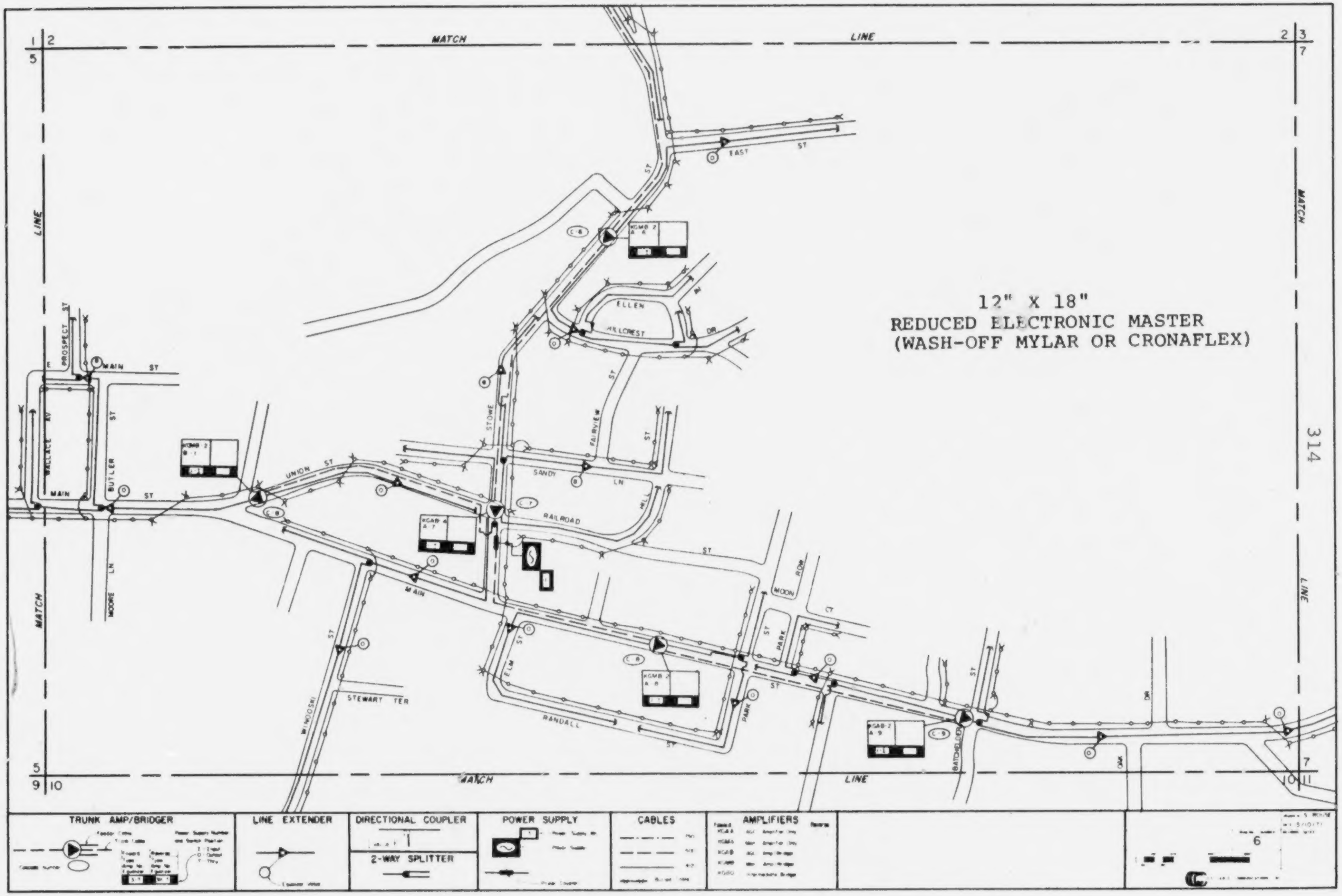
FIGURE 1


24" X 36"
STREET & STRAND MASTER
319
312
MATCH
LINE
EAST ST
ST
ELLEN
HILLCREST
DR
FAIRVIEW ST
STOWE
SANDY LN
RAILROAD
HILL
ST
UNION ST
PROSPECT ST
MAIN ST
WALLACE AV
BUTLER ST
MAIN
MOORE LN
MAIN
WINOOSKI ST
STEWART TER
ELM ST
RANDALL ST
PARK
ST
MOON
ROW
CT
PARK ST
BATCHELDER
ST
DR
OAK
TRUNK AMP/BRIDGER
LINE EXTENDER
DIRECTIONAL COUPLER
2-WAY SPLITTER
POWER SUPPLY
CABLES
AMPLIFIERS
750
500
412
6
S. ROUSE
5/10/71


MATCH
LINE
1
2
5
3
7
9
10
11
FAST
ST
ELLEN
HILLCREST
DR
PROSPECT
MAIN
WALLACE
AV
BUTLER
UNION
STOWE
FAIRVIEW
SANDY
LN
HILL
RAILROAD
MOORE
WINOOSKI
STEWART TER
ELM
RANDALL
MOON
CT
PARK
BATCHELDER
OAK
TRUNK AMP/BRIDGER
LINE EXTENDER
DIRECTIONAL COUPLER
2-WAY SPLITTER
POWER SUPPLY
CABLES
AMPLIFIERS
6

24" X 36"
ELECTRONIC MASTER
(MYLAR SEPIA)

FIGURE 3



12" X 18"
REDUCED ELECTRONIC MASTER
(WASH-OFF MYLAR OR CRONAFLEX)

MATCH
LINE
EAST ST
ST
ELLEN
ARLCREST
DR
FAIRVIEW
STOWE
SANDY LN
HILL
RAILROAD
ST
UNION ST
PROSPECT ST
MAIN ST
WALLACE AV
BUTLER ST
MOORE LN
MAIN
WINOOSKI
STEWART TER
ELM ST
RANDALL ST
MOON
ROW
CT
PARK
BATCHELDER
OAK
DR
TRUNK AMP/BRIDGER
LINE EXTENDER
DIRECTIONAL COUPLER
2-WAY SPLITTER
POWER SUPPLY
CABLES
AMPLIFIERS
6

FIGURE 4

CONSIDERATIONS FOR TRANSIENT AND SURGE PROTECTION IN CATV SYSTEMS

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Director of Research & Development

George P. Dixon
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C-COR Electronics, Inc.

ABSTRACT

Abnormal operating conditions created by transients and surges is one of the most common causes of CATV system failures. Because of the importance of this aspect of system operation much work has been done to "immunize" systems to lightning transients and power line surges. To properly evaluate various protection schemes, the nature of the disturbance needs to be understood, as well as the physical behavior of the protection device.

This paper covers background material necessary for understanding how transients and surges enter and propagate in a transmission system. The characteristics of selected protection devices and their applications are also discussed.

INTRODUCTION

Protection of man-made structures from the effects of lightning has reached a high state of development since the time of the invention of the Franklin lightning rod more than 200 years ago. Overhead power transmission facilities, for example, have been designed to withstand "direct-hits" of lightning. Unfortunately, power transmission systems do not prevent the resultant surge voltage of a direct-hit from propagating and entering other systems which can be damaged by over-voltages. Modern CATV systems are particularly vulnerable to over-voltages because the solid state devices used have inherently low breakdown voltages and low peak power dissipation capabilities. Although lightning is not the only cause of surge voltages in CATV systems, it is, either directly (by direct-hit) or indirectly (via lightning-caused power system transients), responsible for most surges. Power system surges are also caused by switching transients of load-sharing, faults, and power turn-on following an outage. It is reasonable to say, therefore, that the main cause of surge voltages in CATV systems is power system surges. The optimum surge protection scheme for a CATV system depends on many factors. One of the most important is geographic location. Some areas of the country require much more surge protection than others. Also some parts of a system are more vulnerable than others and warrant employment of every useful protection technique.

In the following sections the characteristics of the most common surges in CATV systems are examined, as well as some of the more useful surge protection devices.

CHARACTERISTICS OF SURGES IN CATV SYSTEMS

1. Lightning Transients

The characteristics of lightning have been studied in detail over the past 50 years [1 - 7]. A "typical" lightning stroke is shown in Figure 1. It is characterized by a risetime which ranges from less than 1 μs to more than 10 μs, fall time on the order of 100 μs, and a residual, nearly constant current flow for 100 ms. The peak current for this typical stroke is 20 kA with residual current flow from 20 to 200 A. About 85% of all strokes are caused by electron flow from clouds to the earth, hence a negative-going voltage is produced with respect to earth ground. (About 15% of all lightning strokes have charge flow in the opposite direction, so positive-going surge voltages must also be considered.) Since the waveshape closely resembles an exponential pulse, the frequency spectrum of a lightning stroke can be approximated by the Fourier Transform of the exponential pulse. The power spectrum is the familiar Lorentzian spectral shape. For a waveform with fall time of 100 μs most of the energy is contained in frequency components below 1.6 kHz. However, the peak currents under consideration are so large (~20 kA) that there is appreciable energy at frequencies two or even three decades above this. For a faster fall time stroke (say 10 μs) the half power bandwidth is correspondingly greater (16 kHz) and there is appreciable energy at frequencies to 1.6 MHz and higher.

The single stroke lightning discharge just described is the most common lightning occurrence. Multiple discharges can also occur and when this happens, the waveform consists of a sequence of the single stroke discharges occurring about 1/10 second apart. For multiple strokes the most common number of strokes is six, although as high as 40 have been observed [4].

For protection against direct hits it is clear that the resistance to ground (R) from the strike point must be as small as possible. This means high quality ground bonding should be used at frequent intervals along the line. Fortunately, most aerial CATV cables use utility poles for support. They are, therefore, shielded throughout most of the route by other wires and cables and the brunt of a direct strike is usually borne by the power system wires.

Lightning strikes can cause current flow through the cable sheath to ground without actually striking the sheath. This occurs when lightning strikes close enough to the cable that an induced current flows in the sheath. The magnitude of this inductively coupled current is usually much less than from a direct hit since the coefficient of coupling is low. The induced current depends mainly on the stroke orientation with respect to the line, as well as its proximity. The waveshape of the induced current will be similar to that of the stroke itself but reduced in amplitude.

The main feature of both induced and direct lightning strikes is that they contain energy to quite high frequencies. Since this current is conducted to ground through the cable sheath, a voltage difference which depends on the sheath resistance to ground will develop between the sheath and center conductor., It is, therefore, very desirable to have fast acting voltage limiters at the rf ports of line amplifiers to keep the sheath to center conductor voltage within acceptable limits. This should not be used as a substitute for good grounding, however, since no protection device is completely effective. The better the system grounding, the lower will be the stress on the system protective devices.

2. Power Line Surges

The prime means of introduction of abnormal operating conditions in CATV systems appears to be via surges in the powering system. Although lightning is responsible for many of these power line surges, the mechanism of entrance into the CATV system is usually not stroke induction through the cable sheath but rather conduction through the ac powering system. The powering system is inherently low pass (more precisely, bandpass from 60 Hz to several hundred Hz) and since the lightning stroke contains a large amount of low frequency energy, the filtered lightning surge will be conducted into the rf amplifier housing. The most severe lightning surges are those occurring when a low voltage line is struck. A 20 kV surge on a 240 kV line is barely felt. If the 20 kV surge occurs on a 12 kV line, the situation is severe and even worse when a 240 V line is struck, but this rarely occurs.

Power line surges are also caused by switching transients of load-sharing, line faults, and power turn-on following an outage. These inflict severe stress on the CATV system because they frequently involve over-voltages of about three times normal for times from 1 ms to more than one second. Protection from power line surges can be accomplished using relatively slow devices (e.g. relays, thermal effects and high capacitance protectors). They must, however, be able to withstand high average power dissipation or have a high enough breakdown voltage (say five times that needed for normal operation) to enable network decoupling without voltage breakdown.

CRITICAL SYSTEM PROTECTION POINTS

Some critical points in a CATV system are indicated in Figure 2. From the foregoing discussion it is clear that probably the most important point for system protection is at the power supply station. Here power system surges can be eliminated before they can enter the coaxial cable. A second critical point is the bonding to earth ground. Frequent, high quality ground bonds will greatly reduce direct lightning surge problems. Another critical location is the amplifier station input port, especially if the input is line powered. Surges occurring from sheath current flow must be constrained to tolerable limits at both the power supply input and the rf ports.

SURGE PROTECTION DEVICES

There are many surge protection devices now available that can be used in various combinations to achieve a high degree of surge immunity. Some of the more useful devices are discussed below.

1. Silicon P-N Junction Diodes

Relatively low capacitance diodes (3 pF each) provide limited surge current capability ($\gtrsim$ 0.5 A) and only for short durations ($\sim$1 μs). However, transients can be clamped with back-to-back diodes in 2 ns to $\sim\pm 1$ V. This technique is used mainly for narrowband amplifier protection and applications not involving line powering.

2. Zener Diodes

Zener diodes have intermediate capacitance values ($\sim$30 pF for 1 W devices) and relatively fast switching times ($\sim$40 ns, depending on junction capacitance). They have low surge current capability ($\sim$0.1 A) because of their power dissipation limitations.

Breakdown voltages range from 4 to 200 V and zener diodes are frequently used to trigger other devices which can handle large surge currents (such as SCR's).

Zener diodes can also be used in tandem to provide bipolar limiting to any voltage from 4 to 200 V.

3. Miniature Gas-filled Surge Suppressor [8, 12]

These devices offer low capacitance ($\sim$2 pF), bipolar clipping for voltages $\gtrsim$ 70 V. Lower breakdown voltages are not possible because of the characteristics of Paschen discharge in low pressure gases. Gas-filled surge suppressors have an intermediate response time (~1 μs turn-on time). They can handle large current surges of low duty cycle (~1-5 kA) for 100 μs but do not stand up well under continuous current discharge over 20 A. If their discharge current is limited to 1-5 A, they have a long life. They are useful for limiting peak voltages to ±70 V or so.

4. High Power Gas-filled Surge Suppressor

Because of their larger size these devices have higher capacitance than the miniature types (Capacitance ~7 pF). They have high peak current capability (20 kA) and can withstand correspondingly higher continuous currents.

5. Diac, Triac, SCR's

These devices rely on external circuitry (resistors and zener diodes) to provide accurately controlled turn-on. They have moderate power dissipation capability (~100 W) and find wide application for power supply protection.

6. Time Delay Power Relays

During a power surge these devices disconnect the applied power. They are slow acting (~0.1 to 1 second) and can be programmed to reconnect power after a prescribed waiting time.

7. Varistor [9]

These are metal oxide devices that have a voltage variable resistance. They have high capacitance (~1000 pF) and fair peak current capability (~1 kA for 7 μs). Breakdown voltages range from ~170 to 1400 V.

8. Thyristor, Thyrector, Thyrite [15]

These are mainly silicon carbide devices. They have high capacitance and good surge current capability.

PROTECTIVE DEVICE RELIABILITY

Unfortunately all protective devices will fail if subjected to stresses outside their design limits. It is, therefore, imperative that surge suppressors be prudently used and their operability periodically monitored if maximum system reliability is to be achieved.

SUMMARY

The most common and destructive surge in CATV systems appears to be those from the ac power system. Many power system surges are associated with lightning but they can also be caused by transients of switching and faults. Protection from direct lightning strikes is greatly aided by having frequent, high quality grounds in the system. Additional protection is afforded by voltage limiting devices at active station ports, especially at the power supply input. Power line surges are best controlled at the ac powering stations. Since several locations are usually powered from one point, it is economical to employ quite elaborate protection networks here. The details of protection vary from system to system and even from one part of a system to another. The optimum protection scheme, therefore, must take local conditions into consideration, as well as the characteristics and cost of the protection devices.

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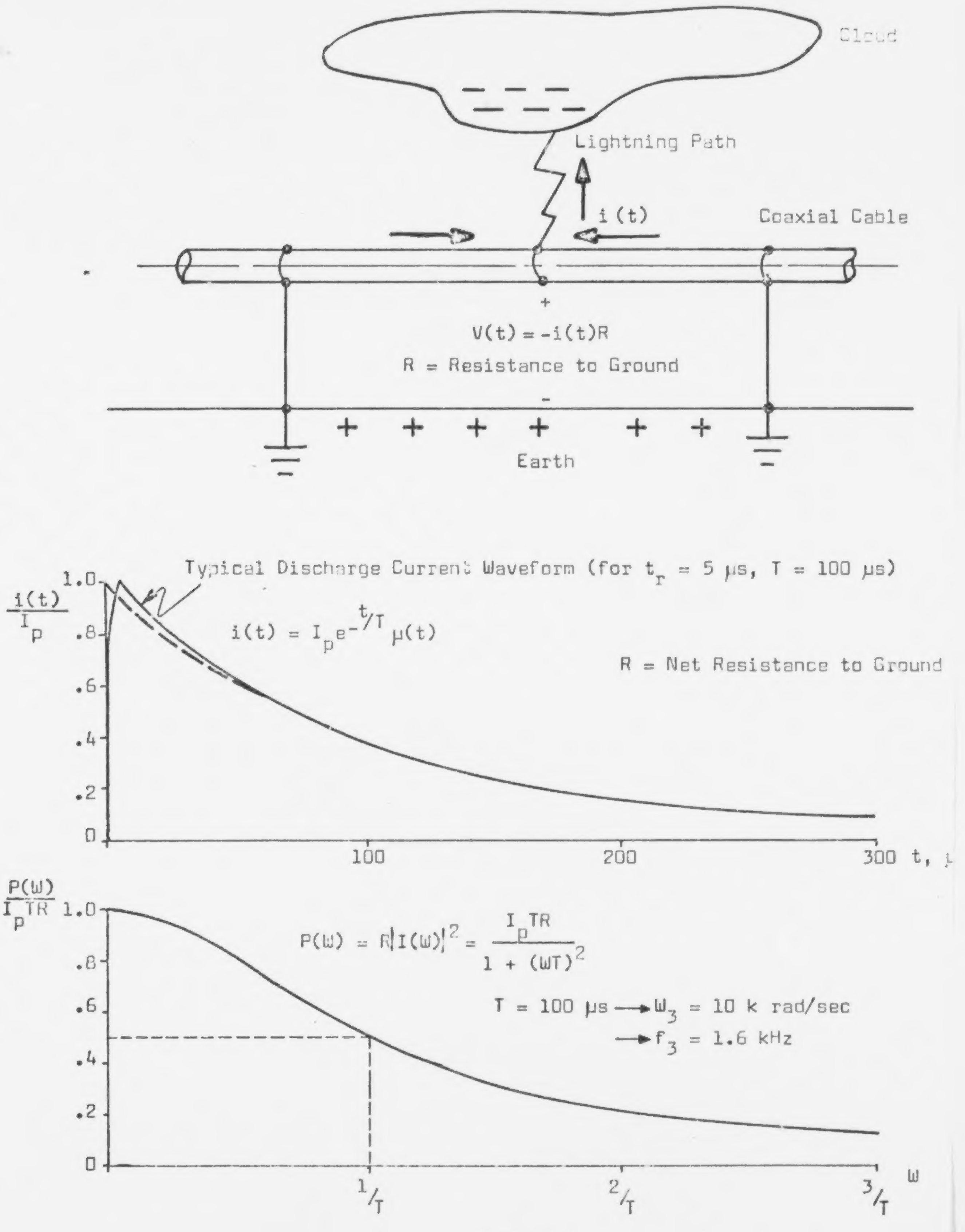
Cloud
Lightning Path
i (t)
Coaxial Cable
+
V(t) = -i(t)R
R = Resistance to Ground
-
+ + + + + +
Earth
Typical Discharge Current Waveform (for t_r = 5 μs, T = 100 μs)
$\frac{i(t)}{I_p}$
1.0
.8
.6
.4
.2
0
$i(t) = I_p e^{-t/T} \mu(t)$
R = Net Resistance to Ground
100
200
300
t,
$\frac{P(\omega)}{I_p TR}$
1.0
.8
.6
.4
.2
0
$P(\omega) = R|I(\omega)|^2 = \frac{I_p TR}{1 + (\omega T)^2}$
T = 100 μs → ω_3 = 10 k rad/sec
→ f_3 = 1.6 kHz
$^1/_T$
$^2/_T$
$^3/_T$
ω

FIGURE 1

NATURE OF LIGHTNING DISCHARGES

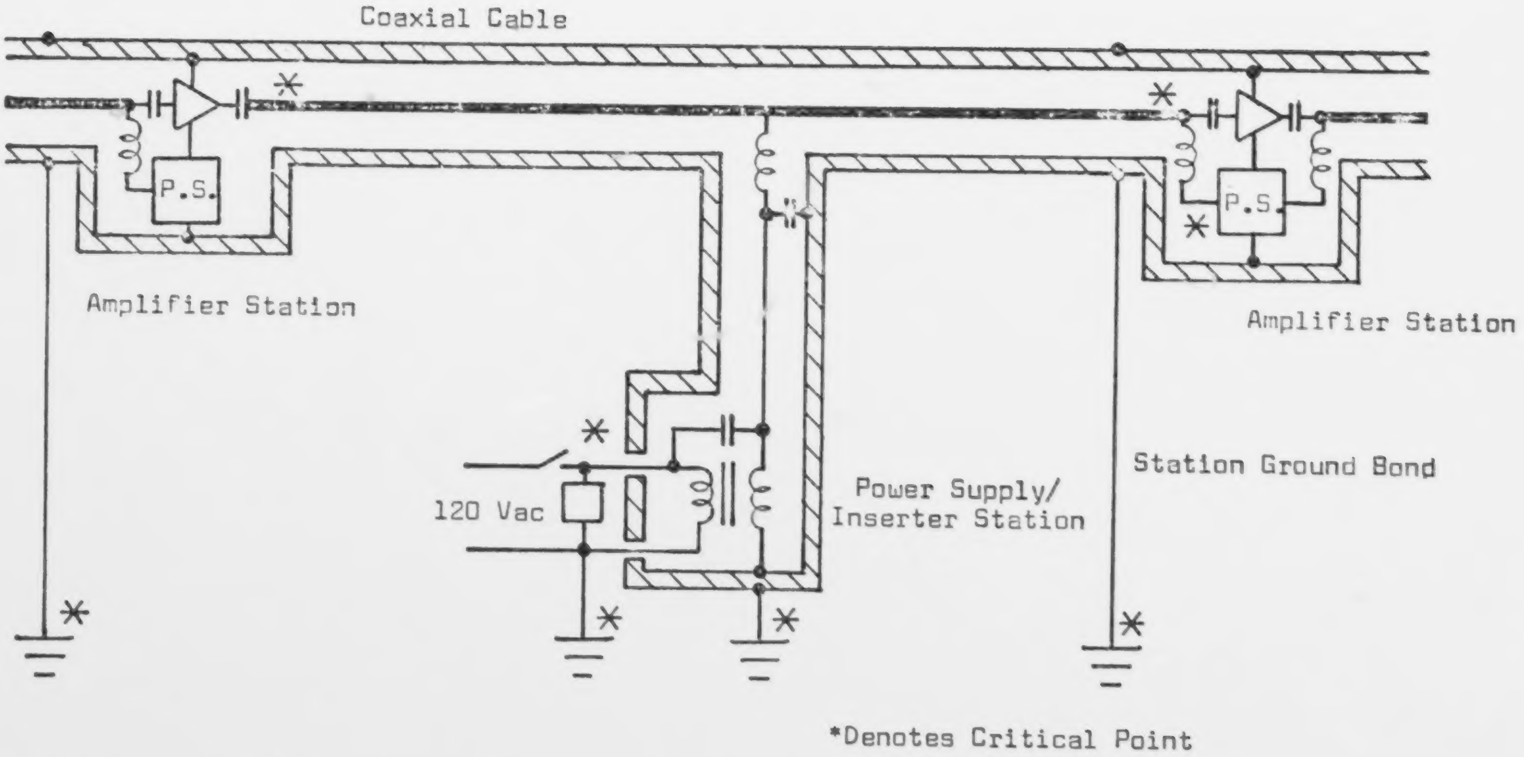
Coaxial Cable
P.S.
Amplifier Station
*
120 Vac
Power Supply/
Inserter Station
Station Ground Bond
P.S.
Amplifier Station
*Denotes Critical Point

FIGURE 2

CRITICAL SURGE POINTS IN A CATV SYSTEM

RESUME OF PRESENTATION

Can Cable System Management and Retreaded Aerospace Engineers Adapt to Each Other?

21st Annual Convention of the NCTA

Paul H. Robbins, P. E., Executive Director
National Society of Professional Engineers

With respect to the subject "Can Cable System Management and Retreaded Aerospace Engineers Adapt to Each Other? ", I can only plead for a rewording of the statement and then an unequivocal "yes". There is a connotation of the word "retreaded" which is most unfair to aerospace engineers.

NSPE has just completed a major study funded by the Department of Labor on the skills conversion of aerospace engineers for use in the new priorities of the nation. This study has shown that the skills available in the technological field from those with aerospace experience are usually transferrable to other areas with a relatively short period of additional training in the nomenclature and application of the science and math they have used in their previous employment.

Unfortunately, this study also shows that there are several commonly held opinions relative to aerospace technical personnel which are substantially unjustified. Although of course there are examples which can be found to prove the "myths", it is grossly unfair to use these few examples and generalize to the total aerospace technological employment.

These myths are:

(1) They will consider any new assignment as temporary and if, and when, a resurgence occurs in the aerospace technology they will leave the new employment to go back. The fallacy of this assumption is two-fold: (1) that aerospace will be reactivated at anywhere near the level of its previous activity; and (2) that individuals who may accept a new direction for their careers are not totally committed to this change. No statistics are available which indicate any extensive justification for this myth.

(2) Because of the nature of the aerospace work, all technical people concerned with it are not cost conscious. It is true that the criteria of aerospace work was first and foremost reliability but aerospace technical personnel were very conscious of the parameters within which they worked and would be equally conscious of cost parameters if this be the requirement of their new assignments.

(3) Aerospace technical personnel are too specialized. While it is true that the assignments to which aerospace engineers and scientists were addressing themselves perhaps have no immediate counterpart, perhaps in new assignments 80 to 90 percent of the science and mathematical background they were applying can be easily transferred to similar requirements in another line of work. A current series of pilot projects being conducted by the National Society of Professional Engineers is proving this point.

(4) They are underproductive. This is perhaps the greatest myth of all, and perhaps is generated by the fact that so many engineers and scientists were utilized in this highly technical field. Those who propound this complaint

oftentimes come from low technology areas where it is difficult to conceive of a highly scientific activity requiring a ratio of technical brainpower far in excess of their experience.

(5) Aerospace personnel were overpaid and are therefore too expensive. Repeated salary and income surveys of aerospace personnel show them only slightly above the averages in the entire technical field. For the most part many of these aerospace engineers are quite willing to accept assignments at the going rate of engineers, which is usually within close proximity to similar work in the aerospace industry.

To revert to our original question, projections for the CATV industry indicate that you are going to have great need for technological people. Many of these will require backgrounds in the electronics and communications fields, and even the remote person from the space industry is aware this was a major activity from which there are many engineers available. CATV management would do well to look to the displaced aerospace engineer to provide a very essential ingredient for the expanded programs with which they will be faced.

FIELD STRENGTH MONITORS

A UNIQUE TEST INSTRUMENT FOR CATV

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INTRODUCTION

A Field Strength Monitor is a new and unique test instrument designed especially for the CATV industry. A Field Strength Monitor combines the functions of a field strength meter, a television monitor, and a video display in one portable instrument. The Field Strength Monitor can be used to measure the signal strength of any VHF or UHF TV signal while observing the picture and sound on the television monitor. This provides the capability to observe any interference in the video or audio TV signals while measuring the amplitude or strength of these signals. The video display provides an oscilloscope-type look at the vertical blanking and sync pulse. This gives an indication of any overloading or sync clipping in the distribution amplifiers. This versatile instrument can be used in the lab to calibrate front-end equipment; in the field to adjust line amplifiers; and in the home to demonstrate the quality of CATV signals.

MODES OF OPERATION

The Field Strength Monitor, FSM, has three modes of operation. A function selector switch on the front panel is used to select the desired operating mode. When the function selector is in the TV mode, the FSM operates as a normal TV. This mode can be used to determine or demonstrate the picture and sound of any VHF or UHF TV channel. The metering circuits are not connected in this mode. When the function selector is in the FSM mode, the FSM operates as both a field strength meter and a TV. The video and audio carrier signals of any VHF or UHF TV channel can be measured while observing the picture and sound. When the function selector is in the Video Display mode, the FSM displays the vertical blanking pulse and the vertical sync pulse on the CRT (picture tube). A block diagram of the FSM system in the FSM mode is given in Figure 1. A similar block diagram of the FSM system in the Video Display mode is given in Figure 2.

SYSTEM CHARACTERISTICS

The FSM can be used to measure the signal strength of any VHF or UHF TV signal from 30 microvolts to 3 volts. A 90 db attenuator is provided in the FSM. The FSM will provide a usable picture on the TV monitor with an input signal of 100 microvolts or more. Any VHF channel from 2 through 13 can be selected on a switch in the VHF tuner. The UHF tuner provides continuous tuning from channel 14 through channel 83. The input impedance to the FSM is 75 ohms. The FSM has a special compensation amplifier circuit to insure that the gain is

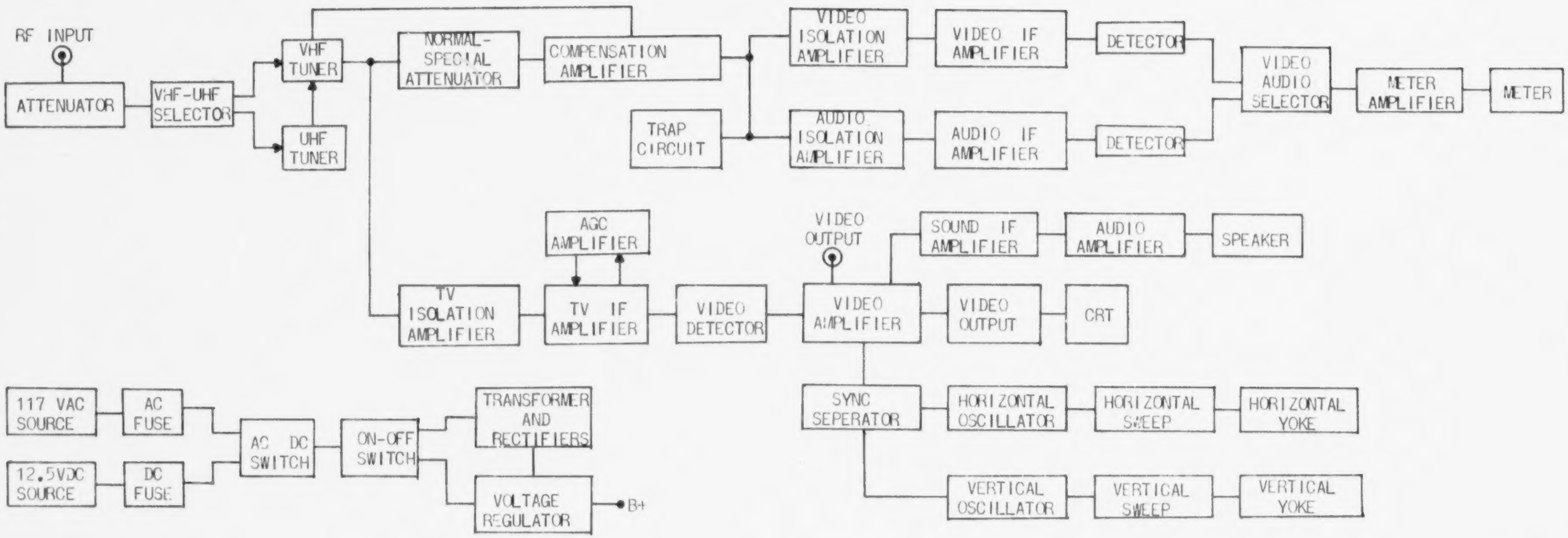

RF INPUT
ATTENUATOR
VHF-UHF SELECTOR
VHF TUNER
UHF TUNER
NORMAL-SPECIAL ATTENUATOR
COMPENSATION AMPLIFIER
TRAP CIRCUIT
VIDEO ISOLATION AMPLIFIER
VIDEO IF AMPLIFIER
DETECTOR
AUDIO ISOLATION AMPLIFIER
AUDIO IF AMPLIFIER
DETECTOR
VIDEO AUDIO SELECTOR
METER AMPLIFIER
METER
TV ISOLATION AMPLIFIER
AGC AMPLIFIER
TV IF AMPLIFIER
VIDEO DETECTOR
VIDEO OUTPUT
VIDEO AMPLIFIER
SOUND IF AMPLIFIER
AUDIO AMPLIFIER
SPEAKER
VIDEO OUTPUT
CRT
SYNC SEPERATOR
HORIZONTAL OSCILLATOR
HORIZONTAL SWEEP
HORIZONTAL YOKE
VERTICAL OSCILLATOR
VERTICAL SWEEP
VERTICAL YOKE
117 VAC SOURCE
AC FUSE
12.5VDC SOURCE
DC FUSE
AC DC SWITCH
ON-OFF SWITCH
TRANSFORMER AND RECTIFIERS
VOLTAGE REGULATOR
B+

FIGURE 1
FIELD STRENGTH METER MODE
FIELD STRENGTH MONITOR

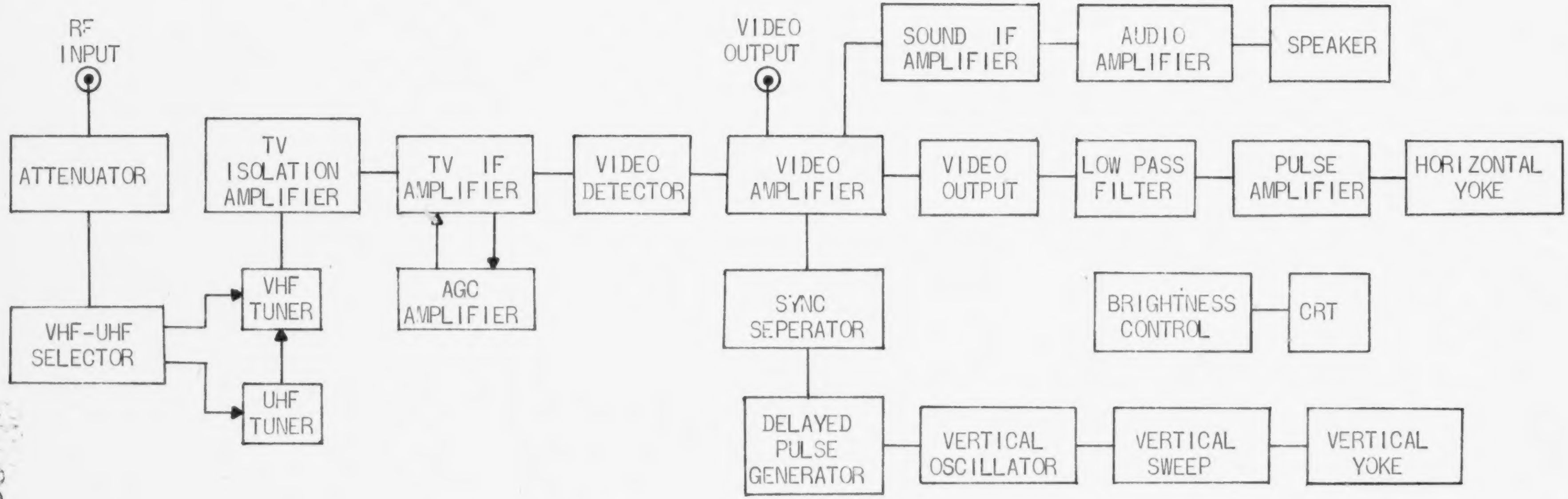

RF INPUT
ATTENUATOR
VHF-UHF SELECTOR
TV ISOLATION AMPLIFIER
VHF TUNER
UHF TUNER
TV IF AMPLIFIER
AGC AMPLIFIER
VIDEO DETECTOR
VIDEO OUTPUT
VIDEO AMPLIFIER
SYNC SEPERATOR
DELAYED PULSE GENERATOR
SOUND IF AMPLIFIER
AUDIO AMPLIFIER
SPEAKER
VIDEO OUTPUT
LOW PASS FILTER
PULSE AMPLIFIER
HORIZONTAL YOKE
BRIGHTNESS CONTROL
CRT
VERTICAL OSCILLATOR
VERTICAL SWEEP
VERTICAL YOKE

FIGURE 2
VIDEO DISPLAY MODE
FIELD STRENGTH MONITOR

the same for each channel. There are three seperate IF amplifiers in the FSM. One IF amplifier is used with automatic-gain-control for the TV monitor. The other two IF amplifiers are used to make field strength measurements. One amplifier is tuned to the video IF frequency and the other amplifier is tuned to the audio IF frequency. The use of seperate video and audio IF amplifiers greatly simplifies the tuning required to make field strength measurements. Field strength measurements are made by selecting the desired channel on the tuner and adjusting the tuner fine frequency control for the best picture and the peak meter reading. The ability to observe the picture while adjusting for a peak meter reading eliminates the possibility of tuning to an adjacent channel or a noise signal.

SYSTEM DESCRIPTION

The RF input connector on the FSM is a type F coax connector.

The attenuator has one 10 db and four 20 db attenuation circuits. The attenuator has a 75 ohm input and output impedance. This permits direct measurement of TV signals on a 75 ohm CATV cable. The attenuator can be used to make field strength measurements from 300 microvolts full-scale to 3 volts full-scale in 10 or 20 db steps. The output of the attenuator is connected to a VHF-UHF selector switch. This switch connects the attenuator output signal to the input of either the VHF or the UHF tuner. This switch also connects the unused tuner input to ground.

A special temperature compensated voltage source is used to provide constant bias voltage to the VHF tuner. This insures a constant gain in the VHF tuner. A special wafer switch is mounted on the VHF tuner to permit compensation for any variation in gain between VHF channels. The VHF tuner is used as an amplifier in the UHF position. The output of the UHF tuner is connected to the input of the VHF tuner. The output of the VHF tuner is connected to a TV isolation amplifier and a normal-special attenuator.

The TV isolation amplifier provides isolation between the TV monitor and the field strength meter. The output of the TV isolation amplifier is connected to the TV IF amplifier. The TV IF amplifier has an automatic-gain-control circuit to provide a constant output signal level for a wide range of input signal levels. The output of the TV IF amplifier is detected and amplified. The resulting video signal is connected to a video output connector on the FSM. This provides the capability to observe the composite video signal on an oscilloscope. The output of the video amplifier is also connected to a video output amplifier, a sync seperator circuit and the audio IF amplifier. These circuits function as a conventional TV receiver to provide the TV monitor portion of the Field Strength Monitor.

The amplifiers in the field strength meter portion of the FSM were designed to provide a full-scale meter reading with a 300 microvolt input signal. This range is needed to measure TV signals from antennas and other low-level sources. The normal-special attenuator provides 10 db of attenuation in the normal position. This increases the normal full-scale meter reading from 300 microvolts to 1000 microvolts without attenuating the signal to the TV monitor.

The compensation amplifier provides a seperate gain control for each channel. This circuit is used to compensate each VHF channel for any variation in gain.

The output of the compensation amplifier is connected to a video isolation amplifier, an audio isolation amplifier and a trap circuit. The isolation amplifiers are used to prevent any interaction between the video IF amplifier and the audio IF amplifier. The trap circuit is used to attenuate the video signal of the adjacent channel to prevent any interference with the audio signal being measured. The video and audio IF amplifiers have three insulated-gate field-effect transistor (MOST) amplifier circuits. Parallel resonant transformer coupling is used between stages. The selectivity of the IF amplifier is controlled by varying the Q of each stage. The AC load resistance of each stage is selected to obtain the desired Q. The audio IF amplifier is more selective than the video IF amplifier because the audio IF signal has a relatively narrow bandwidth. The audio carrier signal level on a CATV system is normally set 12 to 18 db below the video carrier signal level to reduce interference. This is another reason the audio IF amplifier is more selective than the video IF amplifier.

Each IF amplifier has a diode detector circuit to convert the IF signals to a DC signal. The DC outputs of the video and audio IF amplifiers are connected to a video-audio selector switch. This selector switch is used to connect either the video or audio DC signal to the input of the meter amplifier circuit. A matched pair of junction field-effect transistors are used in the meter amplifier to insure temperature stability. The output of the meter amplifier is connected directly to the meter. The meter scale has two microvolt ranges (0 to 300 and 0 to 1000 microvolts) and one db range (-20 to 0 db). The full-scale meter reading in db is always equal to the total attenuation selected in the attenuator.

When the FSM is used in the Video Display mode, the detected composite video signal is disconnected from the CRT by the function selector switch and the horizontal yoke is disconnected from the horizontal sweep circuit. The composite video signal is filtered with a low-pass filter to remove the video information. The vertical blanking and sync pulses are not filtered out of the video signal by the low-pass filter. The output of the low-pass filter is connected to a pulse amplifier circuit. The pulse amplifier circuit generates the power necessary to drive the horizontal yoke with the vertical blanking and sync pulses. The function selector switch also connects a special delayed pulse generator circuit between the sync seperator circuit and the vertical oscillator when the FSM is used in the Video Display mode. The delayed pulse generator delays the vertical sync pulse approximately 8 milliseconds. This places the vertical blanking and sync pulses in the center of the CRT.

The overall accuracy of the FSM in VHF Normal is ± 1.5 db at 25°C. VHF Special and UHF accuracy is ± 3.0 db. The FSM can be operated from either 115 volts AC or 12.5 volts DC.

CONCLUSIONS

A Field Strength Monitor is a unique CATV test instrument that can be used to accurately measure the field strength of any VHF or UHF TV signal while observing the picture and sound. CATV engineers and technicians can use the FSM to detect any noise or interference in video or audio CATV signals. The FSM can also be used to observe the vertical blanking pulse and vertical sync pulse. Antenna radiation patterns can be easily measured and observed with this instrument. Three seperate IF amplifiers are used to insure optimum selectivity and sensitivity. Selected field-effect transistors are used to assure stability and accuracy. The ease with which TV signals can be measured with the FSM will significantly reduce the time required to evaluate or service CATV equipment. The Field Strength Monitor provides an accurate instrument to measure and demonstrate the quality of a cable system.

ANTENNA SITE & HEAD-END SELECTION PROBLEMS IN BIG CITY CATV SYSTEMS

STEVEN I. BIRO
B-RO ANTENNA & HEAD-END ENGINEERING
PRINCETON, N. J.

There are at least three schools of thought on the success of Big City CATV. One is classified by pressing hard for two-way communication, emphasizing the need for customer oriented special services. Wall Street was sold on this idea, and the financial resources are available in most cases to invest and expand two-way communication facilities. No practical experience has proven or disproven the impact of two-way communication yet.

The second group of experts maintain that grand scale local origination, oriented toward local interests, local ethnic and political groups, is the answer for Big City CATV.

Still a third group of experts refuses to accept two-way communication and local origination as the only avenues to succeed in Big City CATV. They believe, and this consulting engineer is one of them, that while local origination and two-way communication represent significant contributions, the majority of Big City people will sign up for CATV if they experience off-the-air reception difficulties, such as ghosty pictures, RF or power line interference problems, missing or disappointing color fidelity, etc.

Thus, the next logical question is: Can CATV really offer better off-the-air reception in Big Cities? All parties must agree: if we do not ascertain ghost and interference free, true color fidelity picture at the head-end, the source of all cable signals, then the quality will not be improved after cascading 25 or 45 mainline amplifiers.

Selection of the proper antenna site, meaningful recommendations for the height and structure of antenna tower, size and configuration of the antenna arrays, can make or break any Big City CATV system.

Before any head-end site is considered for lease or purchase, a signal survey should be performed. Through a signal survey, and only through an on-site signal survey will the engineer be in the position to make recommendations based on actual picture quality and interference observations, not available through computer runs or theoretical signal strength speculations.

THE PREPARATION

Before leaving for a signal survey, it is good engineering practice:

a. To perform a paper study
b. To prepare a signal direction sheet
c. To calibrate and check the test instrumentation.

The need for a paper study may not be that obvious for a Big City survey, but it is a comfortable feeling to have all technical data, program information, distances and bearings available at your fingertips. This will enable the survey engineer to concentrate on testing, while spending less time searching for data and information.

The preparation of a Signal Direction Sheet may eliminate the continous and time consuming search for stations, and in a single 0° to 360° rotation all TV stations could be surveyed and properly recorded.

AT THE SURVEY SITE

Hourly video and sound carrier level recordings on distant stations are in order. However, there is no reason to make hourly interval readings on local channels; their strength will show no significant change during the period of signal survey.

Three day is the minimum recommended survey time for any Big City signal survey, but a 5 day survey could produce even more reliable results. A single day survey may lead to over-optimistic or over-pessimistic conclusions about picture quality, noise and interference problems.

Checking of a single site is false economy. Only several surveyed sites will permit the engineer to match engineering requirements with financial or zoning restrictions, when evaluating survey results.

Constant picture quality and interference observations are the most important survey objectives of any Big City Survey. For these observations the use of a big screen color TV receiver is mandatory. Ghosting and smearing of the picture, color distortions, the presence of interference signals are readily visible on a large picture tube color set. Double shielded cable from the test antenna will reduce direct pick-up problems. A well balanced, grounded balun at the antenna terminals of the monitor receiver will further reduce direct pick-up problems.

An 8 to 10 element Log-Periodic antenna is ideal for survey purposes. A well designed LP antenna exhibits good directivity, (single main lobe), will yield a minimum of 6 dB gain on low-band and more than 8 dB gain on high-band, while maintaining small back and sidelobe conditions.

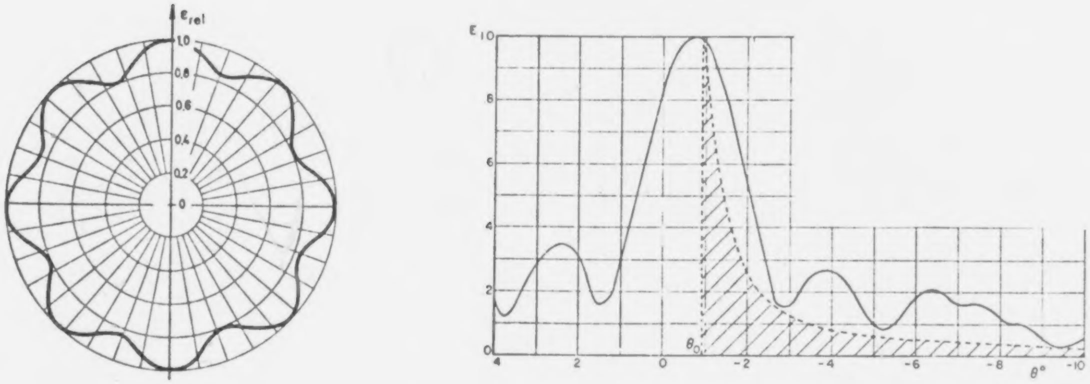
ANALYZING AND TESTING GHOSTING CONDITIONS

Ghosting is one of the most troublesome off-the-air picture interference in any Big City CATV. In order to perform meaningful measurements, to determine the nature, the source and the severity of ghosting, to conduct certain tests for their reduction or complete elimination, it is essential to clarify what are the parameters determining the strength (severity) and nature of ghosting.

Vertical (ground) reflection conditions are influenced by the following factors:

a. The transmitting antenna's radiation pattern.
b. The vertical path profile between the transmitter and the receiving antenna.
c. The reflection coefficient of the ground.
d. The receiving antenna's radiation pattern.

Most TV transmitting antenna radiation patterns are omnidirectional in the horizontal (E) plane. However, in the vertical (H) plane, the patterns show considerable directivity (FIGURE 1). Radiation into the direction of the reflecting ground surface may be significant or well attenuated, depending on the vertical radiation patterns of the TV transmitters. This is one reason why several TV transmitters, operating from the same antenna structure, do not generate the same ghosting conditions.



OMNIDIRECTIONAL PATTERN

HORIZONTAL (E) PLANE

HIGHLY DIRECTIVE PATTERN

VERTICAL (H) PLANE

FIGURE 1

To determine the location of possible ground reflection points it is necessary to construct a scale drawing of the vertical path profile between the transmitting antenna and the surveyed CATV site, showing the exact ground contours. This is best accomplished by using the $7\frac{1}{2}$ or 15 minute U.S. Geological Survey Maps for that area. The distance and elevation data obtained from the maps could be plotted to form a vertical profile by using range-in-feet and elevation-in-feet above sea level measurements for the two ordinates.

The reflection coefficient of the ground depends on surface roughness, type of soil, moisture content of the soil, vegetation growth, frequency of transmission, weather and season. It is also a function of the grazing angle, the angle between the incoming signal and the surface.

The ground reflection coefficient is a complex number, having a certain magnitude and phase, as described by the following mathematical expression:

$$\rho_h = \frac{\sin\psi - \sqrt{n^2 - \cos^2\psi}}{\sin\psi + \sqrt{n^2 - \cos^2\psi}} = |\rho_n| e^{j\varphi_h}$$

where: ρ_h = The ground's reflection coefficient for horizontal polarization
ψ = The grazing angle
$n^2 = \varepsilon_r - j60\sigma\lambda$
ε_r = The relative permittivity of the ground
σ = The conductivity of the ground.

In view of the many variables and unknown quantities above, the accurate prediction of reflection intensity is difficult. On the other hand, an accurate scale drawing of the vertical path can make the vertical reflection point's determination feasable (FIGURE 2).

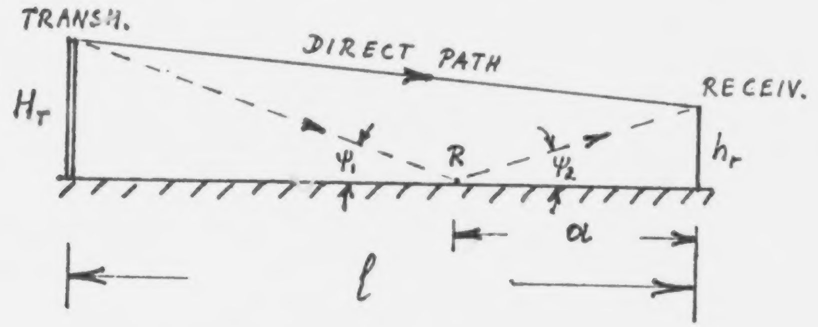


FIGURE 2

The distance of the reflection point from the receiving antenna may be calculated by:

$$\alpha = \frac{h_r \ell}{H_T + h_r}$$

where R = Specular reflection point
ψ_1 = Angle of incident ray
ψ_2 = Angle of reflected ray.

By definition R is the point where $\psi_1 = \psi_2$

The vertical sidelobe structure of the test antenna may also have significant influence on ground reflections. This is exemplified by

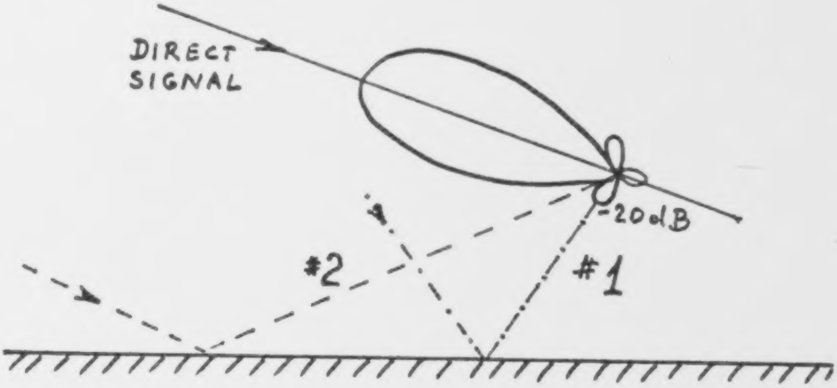


FIGURE 3

FIGURE 3, illustrating the effect of the receiving antenna radiation pattern on the strength (amplitude) of the reflection. While reflected signal No. 2 may suffer 35 to 40 dB attenuation due to the null in the vertical radiation pattern, reflected signal No. 1 will have only a 20 dB attenuation due to the fact that it is being picked up by one of the sidelobes.

EXAMPLE

An on-the-site signal survey performed for Fort Lee, New Jersey resulted in the observation of vertical ghosting conditions on Channel 5, New York.

Pertinent site and propagation information data:

Height of receiving site : 250' ASL
Height of CATV antenna : 550' ASL
Distance to Channel 5 transmitting site (Computer calculated) : 6.35 miles (33,600 feet)
Height of Channel 5 antenna : 1330' ASL

A signal path profile was constructed based on information obtained from a $7\frac{1}{2}$ minute U.S. Geographical Survey Map (FIGURE 4).

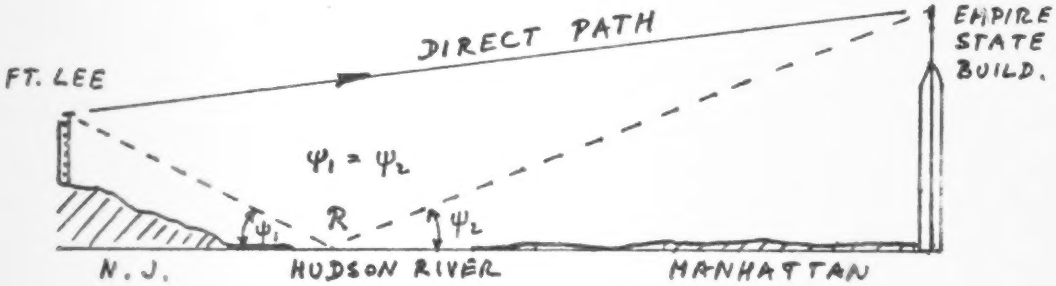


FIGURE 4

FIGURE 4 clearly shows that a significant portion of the propagation path runs over the reflecting surface of the HUDSON RIVER. The location of the reflection point was constructed and found very close to the New Jersey side of the river. The grazing angle was measured as 5.2°. Vertical stacking of antennas to produce a 5.2° first null was not feasable under existing antenna site conditions. However, movement of the antenna away from the edge of the roof resulted in considerable improvements: a portion of the roof shielded the reflection spot while permitting undisturbed propagation of the direct signal.

Note: The vertical scale on this figure has been distorted versus the horizontal scale, thus the reflection angles are considerably magnified.

REFLECTION CALCULATIONS

The reflected signal, whether it is a vertical or horizontal reflection, must always negotiate a longer path than the direct signal. Therefore, the reflected signal will be delayed. Any horizontal displacement on the TV screen is directly related to the time delay, which in turn, can be converted to path length differences between the reflected and direct signals. TABLE 1 is a tabulation of calculated time delays and delay paths as a function of horizontal displacement and screenwidth. Delay path is defined as the difference (in feet) between the reflected and direct path.

	14" SCREEN		17" SCREEN		20" SCREEN	
	TIME DELAY	PATH	TIME DELAY	PATH	TIME DELAY	PATH
1/4" GHOST	1.14 µsec	1125'	0.93 µsec	920'	0.8 µsec	783'
1/2" GHOST	2.28 µsec	2250'	1.87 µsec	1840'	1.59 µsec	1565'
1" GHOST	4.57 µsec	4500'	3.74 µsec	3680'	3.18 µsec	3130'
2" GHOST	9.14 µsec	9000'	7.48 µsec	7360'	6.36 µsec	6260'

TABLE 1

The next, and just as important type of reflection is the horizontal or side-reflection, which could be generated by a number of reflecting objects anywhere in the horizontal plane. The loci of possible side-reflection points of a given displacement form an ellipse, with the transmitting and receiving antennas in the focal points (FIGURE 5).

The equation of the ellipse is:

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1$$

where x and y are the coordinates of any point on the ellipse, $2a$ is the major and $2b$ the minor axis of the ellipse.

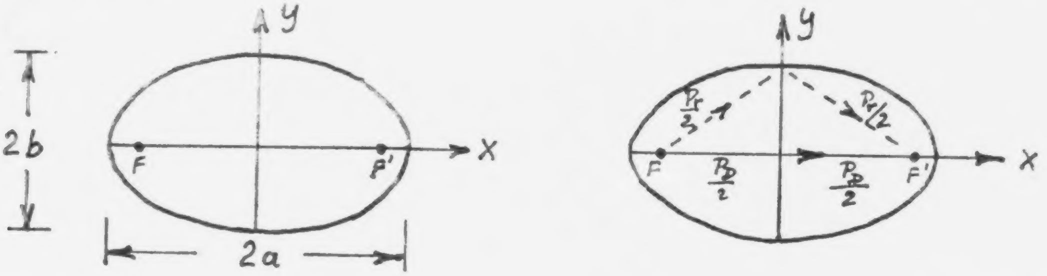


FIGURE 5

Substituting a and b in the equation with P_D (Direct signal path) and P_r (Reflected signal path) as the major and minor dimensions, FIGURE 5, the new equation will be:

$$\frac{x^2}{\left(\frac{P_r}{2}\right)^2} + \frac{y^2}{\left(\frac{P_r}{2}\right)^2 - \left(\frac{P_D}{2}\right)^2} = 1$$

EXAMPLE

The construction of the reflection ellipse is illustrated by the information obtained during the HICKSVILLE, New York signal survey.

We measured a horizontal displacement of 2" on a 14" wide TV screen, representing 9 microseconds in time-delay, or 9,000' in path difference $(P_r - P_D)$ between reflected and direct signal path. The computer calculated distance between the transmitter and receiving antenna site was found P_D =23,7 miles = 124,136 feet. Thus, the reflected signal path should be:

$$P_r = P_D + 9{,}000 = 133{,}136 \text{ feet}$$

The major axis of the reflection ellipse is: $a = \frac{P_r}{2} = 66{,}568 \text{ feet}$

The minor axis of the reflection ellipse is: $b = \frac{\sqrt{P_r^2 - P_D^2}}{2} = 21{,}800 \text{ feet}$

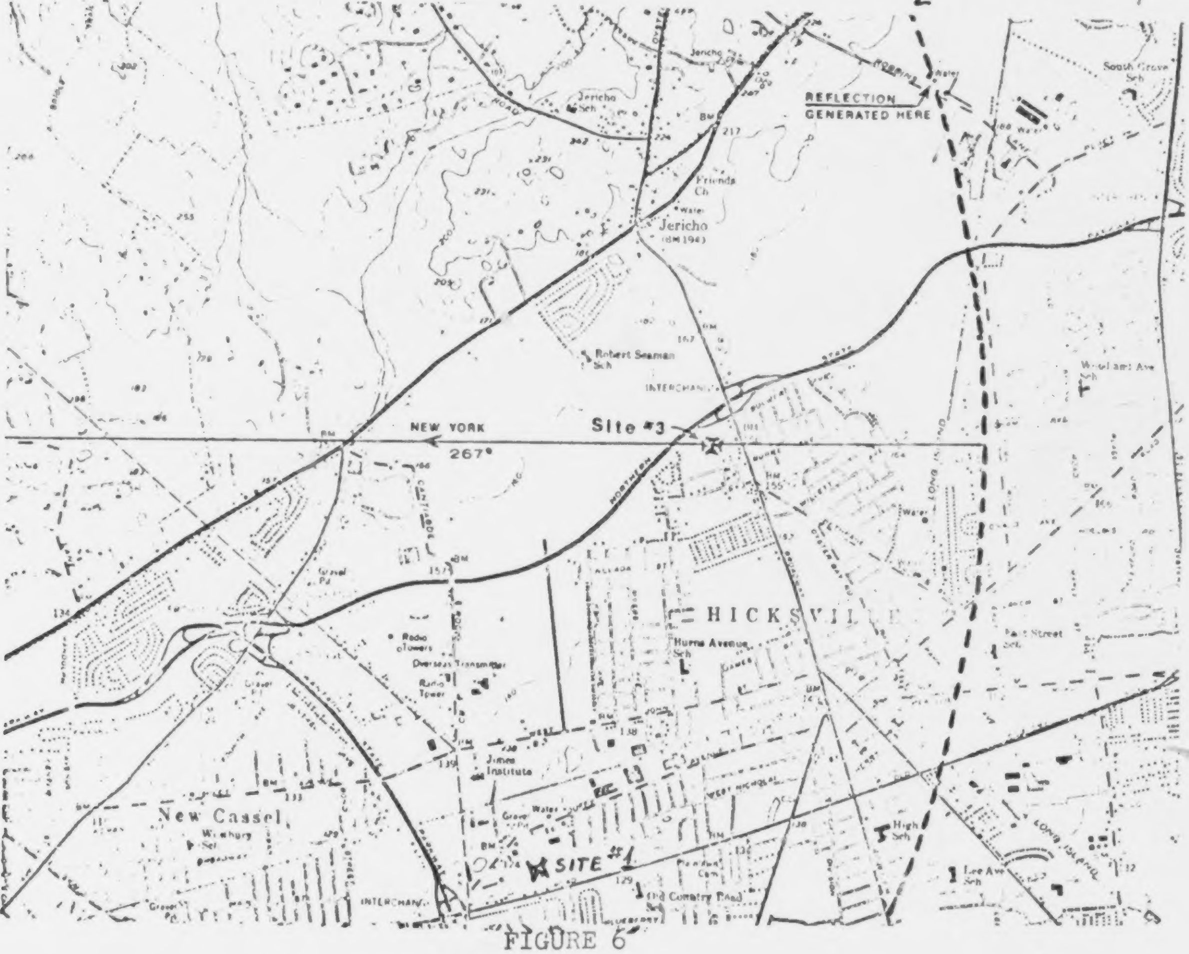

REFLECTION GENERATED HERE
Jericho
Friends Ch
Robert Seaman Sch
South Grove Sch
NEW YORK
267°
Site #3
HICKSVILLE
Radio Towers
Overseas Transmitter
Jones Institute
New Cassel
High Sch
Lee Ave Sch
SITE #1
Old Country Road
INTERCHANGE

FIGURE 6

On FIGURE 6, the reflection ellipse is transferred to the pertinent section of the HICKSVILLE $7\frac{1}{2}$ minute topographical map. Note that the ellipse crosses a watertank located at 30° Azimuth from the survey site. Reflections were generated by this watertank. This has been proven by rotating the survey antenna into the direction of this watertank. The 2" ghost became strong and clear. With other words, while the main lobe of the test antenna was receiving the reflected signal the direct signal became strongly attenuated by the limited side-lobe pick-up of the survey antenna, resulting in a ghost dominated picture. The measured and calculated reflection information provided the basis for straight forward horizontal array-stacking information in order to achieve protection against ghosting.

INTERFERENCE SURVEY

RF interference may occur anywhere in the CATV frequency spectrum, and the problem of checking for its presence and intensity is manyfold. The old approach has been to tune a Signal Level Meter through its frequency range, searching for interference signals. However, the need for frequent band-switching, changing of meter scales, calibration of the meter with varying frequencies, and last but not least, the constant concern that short period transmissions were missed, made the SLM process tedeous and unreliable.

For RF interference surveillance work the spectrum analyzer, with its fast sweep over a wide or very narrow spectrum, less than 1 microvolt sensitivity, 60 to 70 dB dynamic range presentation is a far superior instrument. Better quality spectrum analyzers provide a continous visual coverage of the RF spectrum up to 1200 MHz, they exhibit all signals amplitude and frequency calibrated, easily distinguishing small and large (60 dB) signals next to each other. This is a very important feature compared to the 400 to 600 kHz bandwidth (between half power points) specifications of Signal Level Meters which make those instruments unusable for the measurements or even observation of closely spaced interference signals. Meanwhile, the spectrum analyzer can zoom in and display (investigate) a very narrow portion (5 kHz) of the spectrum with great precision and clarity.

Two-way communication traffic, CB and amateur communication are usually intermittent type of transmissions. If they generate undesired harmonics falling into the frequency range of our interest, the amplitude and frequency of these transmissions can be reliably determined with the aid of a spectrum analyzer.

AM and FM transmitters may also radiate spurious signals, or their strong carriers could overload preamplifiers and converters. Again, a spectrum analyzer will exhibit desired and undesired signals simultaneously, and amplitude/frequency calibrated permitting fast and reliable recording of interference conditions.

Powerline (AC) noise should be first observed on the screen of the monitor receiver as random white spots, or wide bands of lines moving up or down. Again, the spectrum analyzer will not only demonstrate which of the channels suffer the most of AC noise, but the amplitude of the fast moving pulses could be read in dB, thus establishing a firm level of existing AC interference conditions.

TIPS FOR A SUCCESSFUL ON-SITE SURVEY

* DO NOT settle with a single site survey. That might be false economy. Only several surveyed sites will provide the option of matching engineering requirements with financial limitations.

* DO your homework before starting an on-site survey. Computer runs, local maps, 7½ or 15 minute series topographic maps, signal direction sheets should be at your fingertips at the start of the survey.

* DO NOT spend your time taking hourly signal level readings on the local stations if you are within a 15 to 20 mile radius of the transmitters. Their video and audio carriers (within that distance) will be solid like a rock.

* DO spend some time observing peculiarities of the environment. This visual observation should include tall buildings, billboards, watertanks, high voltage transmission lines, neon signs, industrial plants, AM-FM transmitting towers, two-way communications antennas, etc. You may find an excellent correlation between the observed picture quality irregularities and the geographical location of the reflection or noise sources.

* When you CAN, arrange for the participation of the future CATV operator or his representatives on the last day of the survey. This will permit you to get them acquainted with actual picture quality conditions demonstrating some of the experienced reception problems.

There is no written scenario for a Big City Signal Survey. No two signal surveys are alike. A well documented survey, conducted by experts, may bring considerable financial rewards for the Big City CATV operator.

HIGHLIGHTS
TECHNICAL SESSION

TWO-WAY SYSTEM EXPERIENCE

Chairman

Rex Bradley
Telecable Corporation
Norfolk, Virginia

Speakers

James Dixon
Telecable Corporation
Norfolk, Virginia

Ken Chamberlain
Reston Transmission Company
Reston, Virginia

Edward D. McCormick
Community Information Systems
Jonathan Village Center
Chaska, Minnesota

Ralph P. Gabriel
Rediffusion International Ltd.
London, England

Richard T. Callais
Theta Com
Los Angeles, California

Reporter

Donald G. Chandler
Electronic Industrial Engineering, Inc.
North Hollywood, California

1. "The Real World of Two-Way" - James Dixon

The prime thrust of the paper was directed towards the complexity of building two-way systems; that the RFI problems are severe in the 5 - 35 MHz spectrum. There are a large number of RFI emitters in this frequency band. He indicated that the areas that primarily provide RFI access to the system were as follows:

a. At the TV receiver.

b. Into the drop cable.

c. Taps and system distribution cable.

d. At the connectors.

e. Amplifier housing connector interface.

There are, however, solutions to preventing RFI from entering the system. Among these are:

a. RFI tight connectors - with stainless steel sleeves and chromeric "O" rings.

b. Improved drop cables - aluminum 1 mil wrap with braid.

c. High pass filters incorporated into balun at the TV receiver.

Other considerations in a two-way system are:

a. The need for maintenance personnel and test equipment to maintain the reverse system.

b. Segmenting of the design of the system because of noise considerations and to to ease the problem of troubleshooting.

c. System levels in reverse must be kept high in order to provide adequate signal to noise.

Despite the additional problems that are encountered in a two-way system, when proper attention is paid to system design, system materials, and system construction, good two-way systems can be built.

2. "Multi Purpose Frame Grabbing Interactive Experiments at Reston" - Ken Chamberlain

The system at Reston has about 4,000 homes and 62% penetration. The system used is a dual cable plant in the downstream direction and utilizes a third cable for the upstream transmission. The two-way experiments are a joint effort of the Reston Transmission Company and Mitre Coporation. The interactive television system developed by Mitre is called Ticcit for time-share, interactive, computer-controlled information television. An acoustic coupler via the telephone lines is used for the reverse or upstream link. A movie depicting the tests was shown, and is a very impressive audio and visual presentation of the services that have been provided for the test. The bulk of the services appeared to be of an information retrieval type.

3. "Cable Television: A Community Information System at Jonathan" - Edward D. McCormick

At Jonathan and the surrounding community, tests are being conducted in an attempt to define the cable communications system of the future. The U.S. Department of Housing and Urban Development (HUD) is financing the program. Socialogical as well as system evaluations are being conducted concurrently. The information that is derived from the tests will be available to the public, since it is publicly funded.

4. "Two-Way Experience With Dial-A-Program At Dennis Port" - Ralph P. Gabriel

The Dial-A-Program System as applied at Dennis Port, Massachusetts was discussed. The sub low band is exclusively used for video transmission to the subscriber in the 3 to 9 MHz band and all video carriers are phase locked. Each subscriber is connected to the central exchange by means of two balanced pairs in a multi pair cable called a Quist. The larger pair can be utilized up to 16 MHz, which permits up to 2 video channels on one cable. The smaller pair can be used for bandwidths up to 3 MHz. A system will be installed at the Health Sciences Communications Center of Case Western Reserve University at Cleveland, Ohio, in the near future.

5. "SRS El Segundo Interim Test Report" - Richard T. Richard T. Callais

The two-way tests utilizing the Theta Cable System in El Segundo, California are scheduled to start sometime this summer. The SRS System has undergone extensive laboratory tests. The test results to date indicate a substantially error-free perfomance even in the presence of excessive thermal noise. There are a number of configurations of terminal units that will be interfaced with the computer processing center. One of the terminal units is used in conjunction with a paper tape cartridge.

The timetable is to commence the test with 30 prototype SRS terminals, and will be continued and extended with the production and installation of 1,000 pre-production terminals starting at the end of 1972. The 30 terminal tests will be of a technical nature, and the 1,000 terminal test phase will include actual sale of the services.

THE REAL WORLD OF TWO-WAY

J. I. Dixon, Director of Engineering, TeleCable Corporation

Most of you here today will be building and operating two-way cable systems very soon, if you are not already doing so. There is a great deal of information available on two-way systems in general as well as on specific applications as proposed by various vendors. However, in the experience of TeleCable, building and operating two-way is not quite as simple as most of what you hear and read might lead you to believe. So, today I would like to talk very briefly about what we have learned in building and operating a two-way system.

TeleCable installed a two-way system utilizing EIE two-way amplifiers and an interactive system conceived, designed and built by Vicom Manufacturing Company of Dexter, Michigan. This equipment provides us the flexibility and capability of testing and evaluating almost every conceivable type of two-way service.

While there are many considerations in providing such services as shopping at home and education to home-bound students, due to time limitations, I will only talk about interference and maintenance considerations.

Most of you have probably heard at least a rumor that two-way systems have experienced some interference. Well, it's not a rumor. It's a very real problem that must be dealt with. Most two-way gear has been designed to utilize the 5-35 MHz frequency band. Unfortunately, this band is also utilized by many kinds of over the air services. These include amateur radio, commercial short-wave radio, WWV broadcasts, teletype transmission, citizens band services, as well as business radio services.

All of these signals, which are of both local and distant origin, to some degree do get into cable systems that have been built using present day construction practices. There are many variables that determine how objectionable these interfering signals will be in your particular situation. However, I suspect that for most cable operators, it will be necessary to take additional steps to prevent these signals from getting into the cable system. It is convenient to classify the actual means by which these interfering signals are introduced into the CATV system into three general categories. These are (1), the TV receiver, (2) the drop cable, and (3), the cable system itself. So let's consider these in that order.

All of you are quite familiar with ghosts caused by the direct pick-up of the off-air TV signal. The TV receiver is also a very good receiver for signals in the 5-35 MHz band. Signals as high as 0 dbmv in this band have been measured at the TV set antenna terminals and sometimes as high as +10 or +20. One might hope that the amplitude and phase of these signals as picked up by each TV set would be sufficiently random that they wouldn't add. Unfortunately, this doesn't seem to be true. What this means of course is that the TV set must be isolated from the cable system in the 5-35 MHz band. The easiest way of doing this right now seems to be with a filter that only passes frequencies above 50 MHz.

The next item to be considered briefly is the drop cable. Our experience at TeleCable has indicated that the ordinary braided shield drop cable acts as an excellent receiving antenna in the 5-35 MHz band. In the experience of TeleCable, there seemed to be two types which had the best isolation. One had an 8-10 mil thick aluminum wrap. The other cable had a 1 mil aluminum foil on each side of a mylar or polypropylene base, braid and then foil again. Both types of cables have their respective disadvantages so that actually, TeleCable does not use either one of these cables right now. A good compromise solution for us seems to be a cable that has a 1 mil aluminum foil on each side of a mylar or polypropylene base with a 40-60% braid over this. However, since there are many variables involved that haven't been mentioned, I would recommend that you make your own tests before committing yourself to any one type of drop cable. Once you have selected a cable you must decide on the type of fitting to be used and whether it should go over or under the Al wrap. This is rather critical since as much as 20 db reduction in signal pick-up has been observed after replacing improperly installed connectors. And no matter what type of cable you select, you will find that the isolation is not necessarily uniform from reel to reel of cable or even throughout a particular reel of cable. It appears at this time that you will have to measure the pick-up in your drop cable after installation and replace the fittings or cable as appropriate. Again, since I cannot cover all the possibilities, I recommend that you evaluate these factors with respect to your own particular situation.

In the cable system itself, our experience to date indicates that if amplifiers, taps, splitters and the like meet RF radiation requirements, they will also provide adequate RF susceptibility performance in the 5-35 MHz band. The major problem seems to be in what I call the cable-connector-housing interface. There are as many theories about this as there are cable operators and equipment manufacturers. It seems that what works in one area or for one cable operator does not do as well elsewhere. Therefore, I can only highlight briefly some of the considerations that we have found to be critical and indicate what has worked for us.

One of the decisions that you must make is between a connector that is designed to be tightened until it reaches the end of its thread range, or bottoms out, and a connector that has a much greater thread range which requires a torque wrench or similar device to properly tighten it. If one considers only the manufacturers specifications on the connector and the cable, one would probably prefer the connector which bottoms out since this greatly simplifies installation. However, at least one major connector supplier maintains that they received so many complaints concerning their connectors which were designed to be tightened until they bottomed out not making good connections, that they started providing connectors with a greater thread range. Testing by TeleCable has confirmed that indeed something does go awry somewhere between the manufacturers specifications and the cable and connector that is actually installed in your system.

There are a number of possible explanations. As you all know, cable is subject to out-of-roundness which will not necessarily be corrected by tightening of the connectors. Cable is also subject to temperature effects and cold flow. With respect to temperature effects, it has generally been assumed up until now that the radial or axial expansion and contraction of cable is negligible. However, tests performed by TeleCable indicate that this radial expansion or contraction may be quite significant. And lastly, but perhaps most importantly, the installation process itself is a possible culprit.

Apparently, as a result of some of these problems, many connector suppliers now offer stainless steel sleeves as an option. While the sleeves themselves are not expensive, they can significantly increase your installation costs due to the additional time required to insert them. Another option being offered by some connector suppliers is a conductive "O" ring. Hopefully, this would insure a low RF impedance through the connector. This "O" ring is relatively expensive but there would be no additional installation costs. However, it seems possible that the apparent cable O. D. variations we have been speaking of up to now could also reduce the effectiveness of these devices. Other alternatives that might not be so dependent on cable O.D., would be a conductive lubricant or a conductive water-proofing compound or some type of ferrite ring designed to absorb energy in the 5-35 MHz frequency band.

Actually, while TeleCable continues to test these options for effectiveness, we have not yet found it necessary to use any of them. At this time, we have found that the following will provide us with a tight system. (1) A careful, conservative matching of connector and cable specifications, (2) extra time and effort during installation and (3) extra attention to overall quality control.

The other area that I wanted to touch on briefly today is maintenance. Two-way in a cable system is not a little extra that can be handled in the spare time of your regular cable technicians. You should think of the reverse system as a second cable system which must be staffed accordingly. In addition to the cable system, you will usually have some type of terminal equipment at the subscribers which you will either have to maintain or arrange for a service contract with the firm that supplied it. In addition to this, there will be some kind of central control and processing equipment. Quite often, this involves a very sophisticated computer. Again, you will either have to train additional technicians to take care of this equipment or arrange for some kind of service contract with the company that supplied you with this equipment. Also computers seem to insist on being told what to do. Most of you who are familiar with computers will agree that you quickly find changes that you want to make once you get into operation. You will want to add or delete subscribers or add or delete information that you provide or have it provided in a different form or expand its capabilities. This means changes in what is known as the software. Now software can be much more expensive than hardware initially. But more importantly, changes to software can be very expensive and time consuming. If you have a large operation, then you will want to provide your own progamming capability. If you only have a small operation, be sure to ask who is going to make these changes, how much it will cost and how much time it will take.

Maintenance of the reverse cable itself can present some rather interesting problems. At first you will probably not have signals on the whole system all the time as you do in the case of the forward system. In all likelihood, you will have fairly long sections that do not have any kind of reverse system subscribers. What this means of course is that you can't just pick up a FSM and go make a quick check on the operation of your reverse system. Even where you do have subscribers whose terminals are being sampled every 30 seconds or so, as in most 2-way systems, you might still have a problem. Let's say you are trying to find out how many people are watching channel 2. How do you know the difference between no response because (1), someone not watching channel 2, (2) the TV set and/or terminal equipment is off, or (3) because there has been a failure in the reverse cable system.

Many of you may have to obtain test equipment that you haven't needed up to now. Some of it, such as spectrum analyzers,are quite expensive. Also if you do not want to go into subscribers homes to send signals back for reverse system testing you may want to provide some type of van with appropriate test equipment and power. The type of testing and maintenance schedule that you set up will probably depend in part on whether or not you can correct the failure in the reverse system without interfering with or otherwise affecting your subscribers that are on the forward system. This is something you should look at carefully before committing yourself to a particular type of system.

Actually, I suspect that you will find your greatest problem in the maintenance of the reverse system is in the control of interference. To locate the source of interference could be quite a problem if you have two or three hundred miles of system in operation. Thus, it is highly desirable that your system be segmented in some way, much as most suppliers suggest that you do for control of noise or noise build-up. Thus, in a hub system, you could quickly isolate the source of interference to a particular spoke of your hub. However, this can still leave quite a significant amount of system in which to locate the source of the interfering signals. Even in one particular spoke of a hub, there can be many, many connectors, drop cables, and TV sets to check. One way to locate the source of interfering signals is to disable sections of the reverse system. Since most of the systems we are talking about do involve some kind of computer, it seems that the ideal long range solution is to build some means into the amplifiers to turn them on and off remotely with the computer. In the meantime, you will probably want to disable the reverse amplifiers manually. Actually, if possible, you will probably find it very desirable to keep most of the reverse system disabled when you are not using it. This will greatly simplify the task of finding the cable section that is causing the interference. There is another benefit to this too. Keeping local radio services such as hams out of the cable system can be a major task. Thus, it would simplify your operations if the area that the ham is in is disabled in the reverse direction when you are not using it. Of course, if you are providing a relatively limited bandwidth service such as digital only, you might think that all you would have to do is select a frequency that isn't in the ham band and you wouldn't have any trouble. That may or may not be true. It is possible for ham signals to get into amplifiers and generate many beats. Although there is not time to go into it today, required signal levels have not received sufficient attention with respect to operation of the reverse system. But that must be the subject of another talk at another time.

Today, I have highlighted briefly two particular areas that you should consider in building and operating a two-way system. If you are to use the 5-35 MHz band, special measures must be taken to prevent the introduction of undesired signals into the cable system. Maintenance of the reverse system requires a full staff, possibly some specially trained technicians, and some careful planning ahead before you build the system. There are many other considerations which we have not been able to go into; one which I mentioned very briefly at the end was levels. Two-way is not just a nice little extra that you get practically for free. It is a complete system in itself with its own special problems which require a system engineering approach.

I hope I have not discouraged you about two-way. We at TeleCable are still very enthusiastic about it and are proceeding with further experiments and testing. Recently, we have successfully used our two-way system to enable the local schools to cablecast a mock Republican and Democratic National convention and election. Very soon nurses in local nursing homes will have complete two-way video, audio and digital communication capability with doctors in a local hospital. Two-way works. It is just that two-way must be given the same careful attention and thought as your forward system is presently given.

MULTIPURPOSE FRAME GRABBING INTERACTIVE EXPERIMENTS

K. W. Chamberlain, V. P. of Reston Transmission Company
A Division of TeleVision Communications Corp.

I would like to preface my talk this morning with a quotation from a speech given this year at the Southern CATV Convention by Mr. Alfred Stern, president of TVC; "With our industry's rapidly advancing technology, metro-cable systems will soon be fully capable of making the subscriber home the central point in a total communications grid."

In a few minutes you will see a film of the computer demonstration in Reston which will dramatically illustrate what I believe Mr. Stern is referring to.

But first, a few words about Reston and our cable system: (See figure 1) Reston is a new planned city located 20 miles west of Washington, D. C. which will have 30,000 living units by 1980. Currently there are about 4000 homes of which 62% are cable subscribers.

We presently have fifty miles of dual underground plant with a capacity of 40 channels. On the A system we are carrying 3 network channels, 2 independent channels, one educational channel all from Washington and our local origination channel. On the B system we offer three network channels from Baltimore, a weather channel and a news/stock channel. Fourteen FM radio stations are also carried on both A and B systems. We are providing limited two-way service from the village centers back to the head-end by a third cable which is used primarily for live program origination. The final element in our planning for future requirements was to bury a six pair telephone cable with the trunk and distribution system.

Our management was approached by the Mitre Corporation in January 1971 to participate in a cooperative experiment in interactive television by providing the use of one of our available channels. Incidentally, they are a nonprofit research and systems engineering firm whose work is sponsored by various governmental agencies and foundations.

The plan was to microwave the output of two on-line computers located eight miles away in McLean, Virginia, to our head-end where the signal would be transmitted on channel 7 to all subscribers. (See figure 2) Since the subscriber already has a good display device in his TV set and the return path via his telephone, we only needed to add a control box and a frame grabber to complete the home terminal.

The film we are about to see shows the type of terminal operation we have been testing in Reston since June of last year. This particular film was produced at the studios of WETA-TV in Washington, D. C. for use by the Public Broadcasting Service.

The demonstration is introduced by the co-developer of the system, Mr. Kenneth Stetten, an information scientist for the Mitre Corporation.

Film Synopsis

The 16-mm color film runs for 22 minutes, and consists of a live demonstration of the Reston-type home terminal equipment being used to interact with a distant computer producing assorted suscriber-services examples. Kenneth J. Stetten, co-inventor of the system for Mitre, introduces Jack Marsey, his associate, who then conducts the system demonstration.

Seen in the various close-up and general views are a home television set with a video tape recorder and control box on top, and a regular dial telephone with touch-tone adapter, all being operated by the demonstrator. (See figure 3)

Upon completing a telephone call to the distant computer facility, the first page of a "Services Directory" appears on the TV screen. The directory lists such services as "Desk Calculator", "Educational Materials", and "Medical Information" and the keys to be pressed on the touch-tone pad to obtain access to them. This keyboard method of response to the computer is called the "Private" or "Interactive" mode of terminal operation.

The "Desk Calculator" is selected and appears as a five-line "grid" of number spaces with a column of control functions for various arithmetic operations. Numerals snap into grid positions as they are entered by the keyboard. Numbers are instantly added, subtracted, multiplied, and a square root extracted. This calculator program not only shows a useful home service, but emphasizes the advantages of digital (pulse form) data storage over analog (picture form) storage. It takes less storage space in computer memory, and enables full machine capacity for logical computation (arithmetic here) on data before sending back displays to the user.

As an example of information retrieval, a list of "Community Organizations" located in the town of Reston is next called up. Various text informational pages are displayed on demand from the keyboard, by typing page numbers, "next page", "previous page", or "index" pages. This program illustrates the "random access" capability of computer-controlled digital data storage.

"Educational Materials" are typified in the form of an arithmetic sequence called "Carry". Problems in addition are offered on the TV screen, and when a correct answer is typed in, the display shows the correct answer in proper position and the word "Correct" alongside. A wrong answer draws a "No Try Again" print-out on the screen. On the second consecutive wrong typed-in answer, the computer reveals the correct solution on the display. Repeating a given page of problems results in a different set of random numerals substituted in the same problem structures.

By keyboard control, several sections of the course are skipped over to get to the actual "carry" sequence. A two-digit problem (37 + 25 in the example) requiring carrying a "one" over to the left column is done first in three partial additions to avoid carrying over. Then the idea of writing the "one" over the left column of digits is graphically developed, enabling the learner to grasp the mechanics, and drill on random-number carry problems repeatedly. A "fill-in-the-blanks" type format is next shown. Then, the computer is asked for a score-on this section, and instantly displays the number of correct and total tries with a percentage grade. Shown in this program is just an essence of the instructional power of "CAI" (computer assisted instruction).

A "Tax Guide" for IRS Form 1040 is glimpsed from the "Financial Information" service list. In this sequence, the subscriber can selectively obtain help on any portion of the form that he wishes, without having to "thumb through" the intervening explanatory material. This program is an example of the many kinds of reporting and application forms that are adaptable to computer programming for user aids.

How a housewife, whose child has sipped some kerosene, is helped is next illustrated by calling up "Medical Emergencies" from the main services directory, then "Poison", and then "Gasoline-Kerosene" to see the correct antidote. The two-way capability is exercised in another way by "notifying" the nearest hospital via computer of the pending arrival of the sick child.

Additional services are shown under "Medical Information" in which a list of nearby doctors is quickly found, and even more detailed information displayed. An appointment with a doctor is made through the computer-managed central memory.

The second page of the main services directory is keyed and lists such items as "System Instructions", "News

Sports and weather", "Telephone Book", and "Welfare Services".

"Welfare Services" turns out to be a "privileged portion of the data base, and requires that a password (or code number) be typed in first to authenticate the caller. When so done, the first page of a "Private Directory" of professional doctors' services is offered with such items as "Communicable Diseases Resume", "Drug Information", and "Scheduled Appointments".

When "Scheduled Appointments" for "Today" is examined, the appointment made earlier under "Medical Information" is listed, along with others. Appointments for a future date are also shown.

A concept of electronic mail delivery is developed by calling for "Mail" from the second page of the "Private Directory". A list of items available for delivery are displayed, these messages presumably having been previously typed into central storage by the senders. A personal letter is selected, read, and then "released" or "erased". A dentist's bill for services is shown and "paid" electronically, using the subscriber's personal charge account or bank identification number.

The telephone is hung up and the terminal placed into the "Public" mode of operation by a control box switch (top of TV set). A series of up to 300 popular information pages can be dialed by the "subchannel" selector switch on the controller. Such services as a public program directory, baseball scoreboard, stock reports, fishing reports, racing form consensus, classified ads, TV listings, voter registration, bus schedules, recycling information, recent book arrivals at the library, and a school lunch menu are selected. Even though a one-way type of cable service, this mode shows that hundreds of informational sub-channels may be effectively supplied within a single TV channel space, with aid of a frame-grabber.

The controller is then changed to show the "raw" time-division multiplexed signal (no frame-grabber operating) flashing by at 60 fields per second. The vertical hold of the TV set is displaced to show the vertical blanking bar in mid-screen, preceded by a fast-changing line of bright dashes which is the 16-bit binary "address" code which identifies each of the following fields of data. (See figure 4) This code is normally masked off at the bottom of the screen, keeping it invisible, but enables selective frame-grabbing under control of an address decoder in the control box. This feature not only enables the user to manually select "Public" subchannels, but in "Private" mode, a special address, unique to each terminal, is activated so that the interactive computer responses will be frame-grabbed only by the subscriber terminal requesting them. (Film concluded at this point.)

Since the introduction of the system at the NCTA convention in Washington, D. C. last year, nearly 1500 people have attended the demonstrations, representing the general public, educators, the government sector and many of the major equipment manufacturers.

Following each demonstration the participants were asked to complete a questionnaire to assist us in developing some ideas on the potential demand for these services and the extra amount they would be willing to pay for each of the six groups of services.

The tabulated results of this survey showed the following:

1. 78% would pay an average of $1.70 per month for the one-way services, i. e. weather reports, TV listings, bus schedules.
2. 75% would pay an average of 60¢ per month for a calendar of community events.
3. 33% would pay an average of 28¢ per month for a personal address and telephone listing.
4. 40% would pay an average of 63¢ per month for a personal stock profile on their own portfolios.
5. 72% would pay an average of $4.13 per month for the home calculator.
6. 95% would pay an average of $1.33 per computer hour for computer-aided instruction courses in algebra, French, car repairs and others.

The Reston demonstration has achieved three main objectives: it has contributed to widespread interest in two-way interactive TV among manufacturers and cable operators; Government planning groups have been made more interested in the social impact and public service possibilities; finally, the technology has been shown to be here and ready, even though further refinement of the system is needed to effect cost reduction and improve the packaging of the hardware.

I would like to conclude this talk by outlining three of the current goals for this system: first, in Reston experiments will be conducted with low cost two-way video communications (similar to picture phone) which will use one TV channel for several dozen simultaneous face-to-face calls. Second, the Reston interactive system will be expanded beyond the "sterile" laboratory type experiment by putting terminals in homes to get unbiased reactions to the whole idea of interactive TV services. These reactions are essential in the development of marketable software. Finally, a similar system will be installed in a junior college where computer-aided instruction courses will be tested.

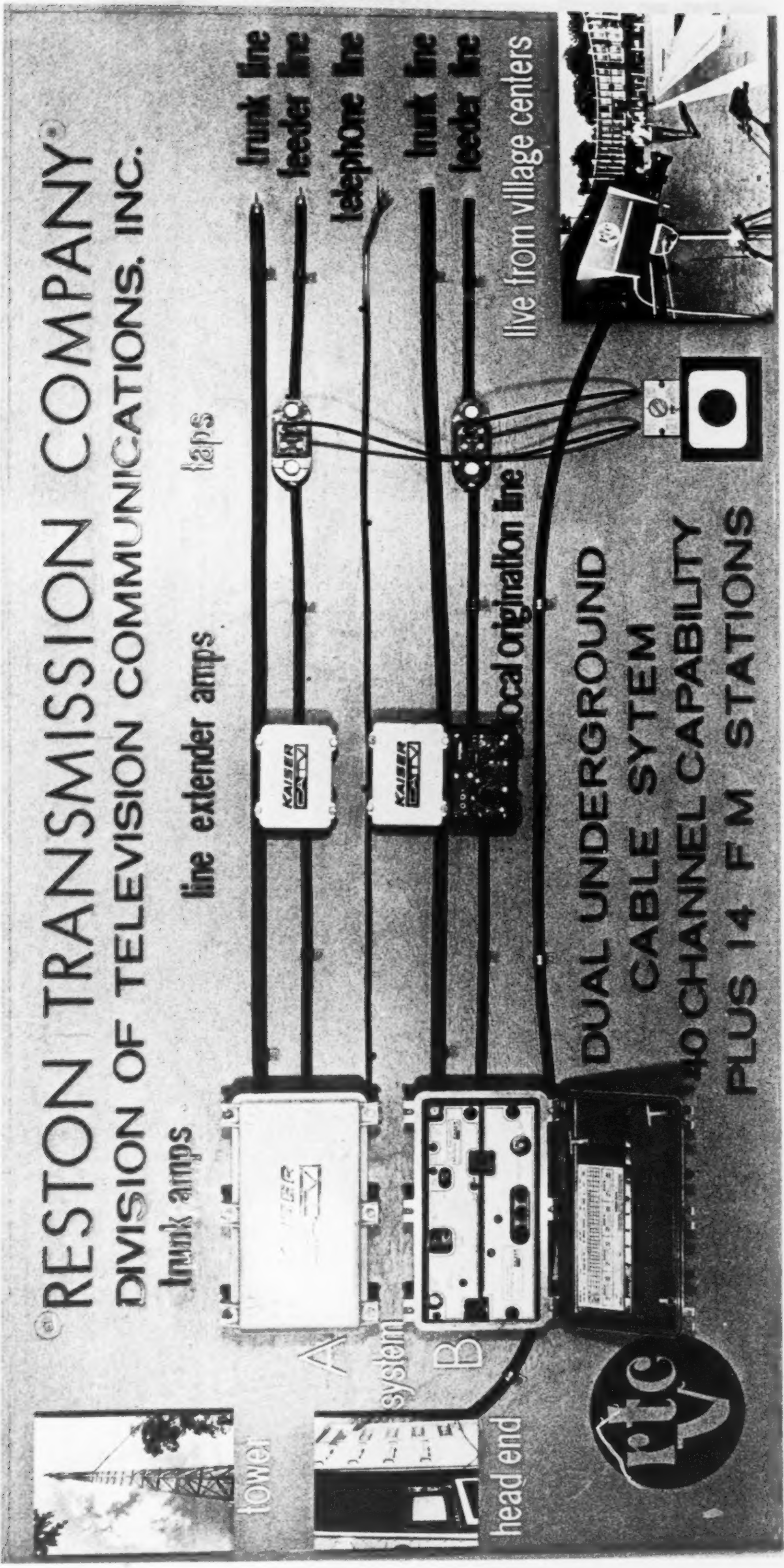

RESTON TRANSMISSION COMPANY
DIVISION OF TELEVISION COMMUNICATIONS, INC.
trunk amps
line extender amps
taps
trunk line
feeder line
telephone line
trunk line
feeder line
live from village centers
local origination line
DUAL UNDERGROUND
CABLE SYTEM
40 CHANNEL CAPABILITY
PLUS 14 F M STATIONS
tower
head end
system
A
B
KAISER CATV
KAISER CATV
rtc
tv

FIGURE 1

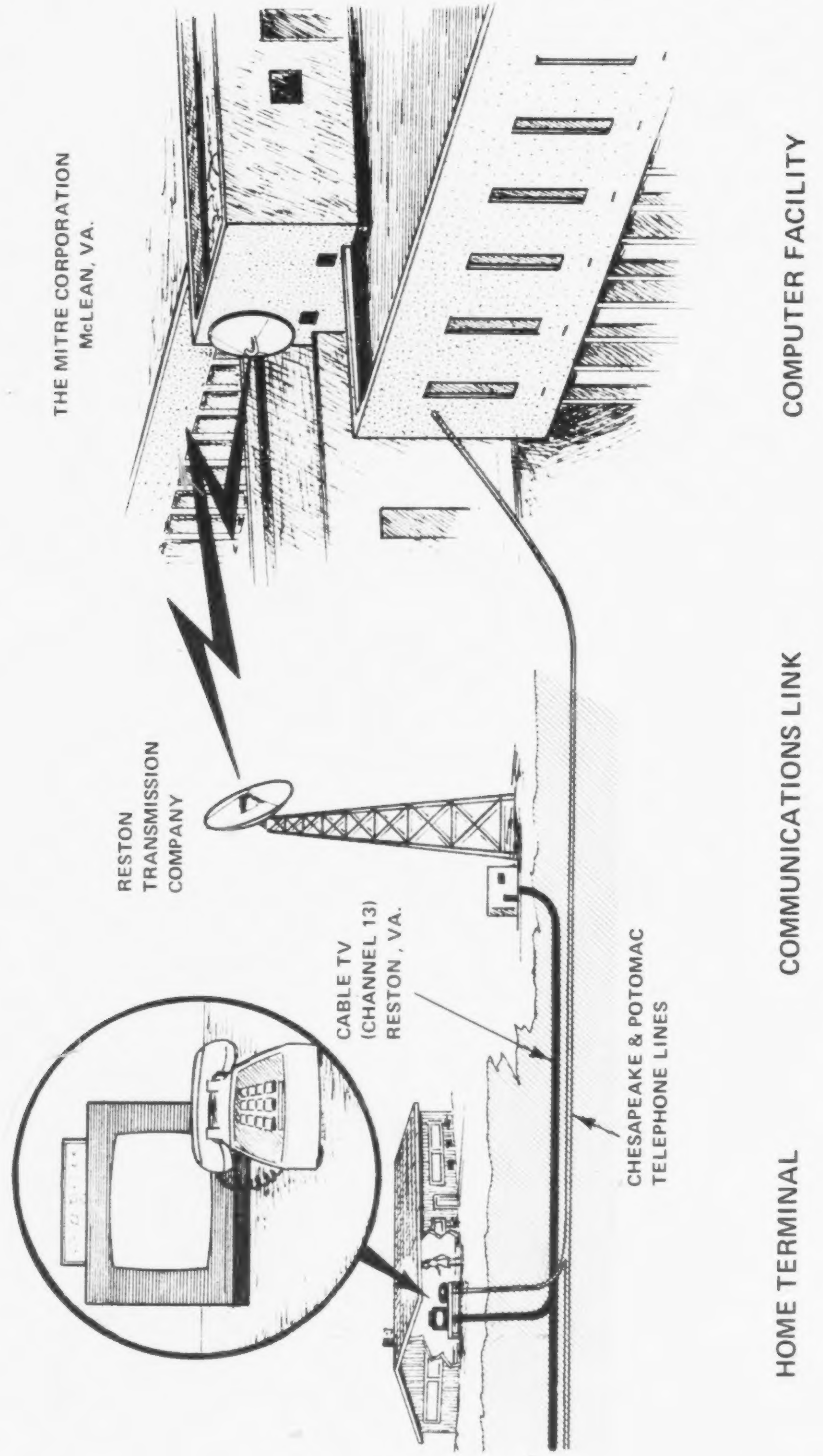

HOME TERMINAL
COMMUNICATIONS LINK
COMPUTER FACILITY
CHESAPEAKE & POTOMAC TELEPHONE LINES
CABLE TV (CHANNEL 13) RESTON, VA.
RESTON TRANSMISSION COMPANY
THE MITRE CORPORATION McLEAN, VA.

FIGURE 2

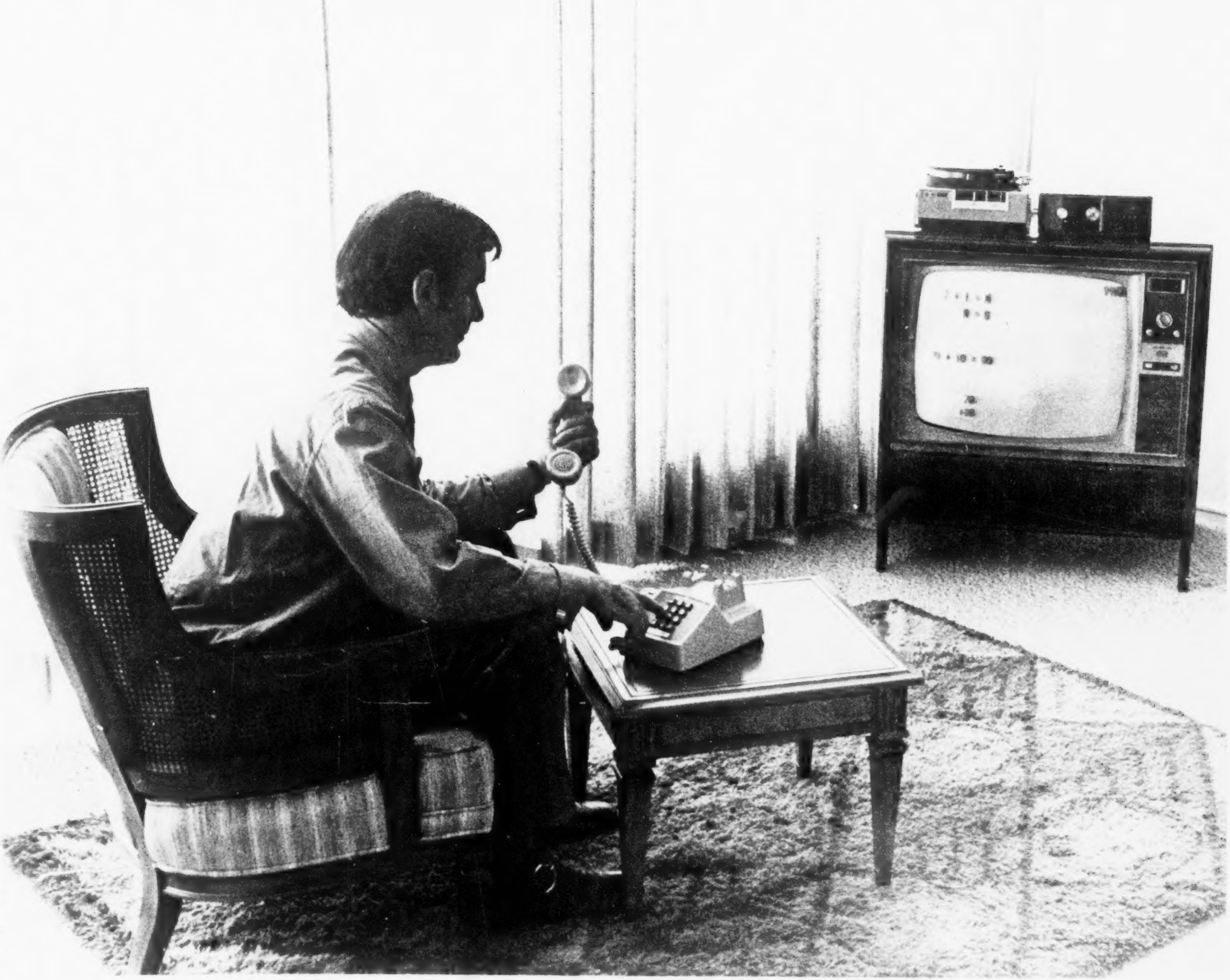


FIGURE 3

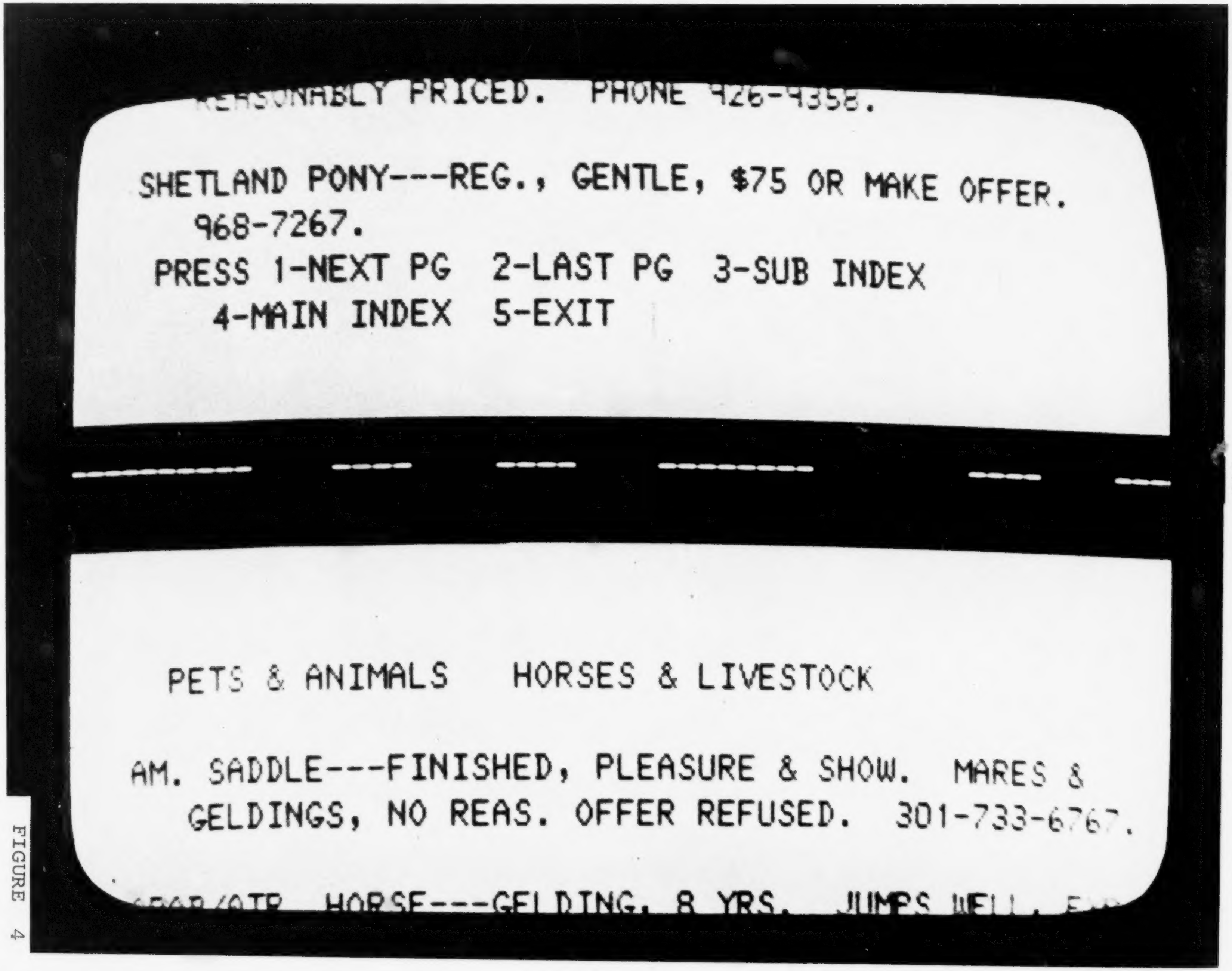


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FIGURE 4

CABLE TELEVISION: A COMMUNITY INFORMATION SYSTEM AT JONATHAN

E.D. McCormick
President
Community Information Systems, Inc.

At Jonathan, Minnesota today, people are using "Responsor"^{tm} units as part of a demonstration of what the two-way cable system can offer. This demonstration is made possible through a grant from the U.S. Department of Housing and Urban Development to Community Information Systems, Inc. We all know that the general public has little or no idea of what two-way cable into their homes will really mean. None of us knows the full potential. We do know that by putting the "Responsor"^{tm} units in the hands of enough people and inviting them to use the units to tell the system what they want, we're going to expand their vision of how cable communications can more fully serve their needs, and, in the process, we in the industry are going to become much wiser as to the wants and needs to be fulfilled.

One-way television broadcasting and one-way CATV systems have taught the public to expect little in the way of response from their television sets. Nicholas Johnson surprised them with his book, How to Talk Back to Your TV Set; talking back was a new idea to most viewers. However, now in a much more immediate way with two-way amplifiers, and terminals capable of sending and receiving subscriber signals, we are entering the era of two-way cable systems when information systems will be offered on a massive scale. The demonstration system at Jonathan is perhaps the first to so thoroghly break through the stereotypes of one-way broadcasting, enabling the individual to think more vividly in terms of what he can ask for from this two-way medium. There is no substitute for the hands-on experience that we offer them. No verbal description, no slides, no movies will give a person as deep an impression as he gets from actually using the equipment the Community Information Systems now has available to the public in the new town of Jonathan in the City of Chaska, Minnesota.

Jonathan is a planned community on 5,000 acres about 25 miles southwest of Minneapolis (Figure 1). Within 15 years, Jonathan will probably be the home of at least 50,000 people with 15,000 subscribers to the two-way cable system. Communication is being carefully planned in Jonathan and will play a vital role in the development of this new town. For example, the educational system in Jonathan can take a completely new form with new methods of teaching. Health care delivery can be made more immediate, serving greater numbers of people more efficiently.

In Jonathan, the cable television network is redefined as a Community Information System where the conventional concept of television entertainment plays but a small part of community services to be provided. This Community Information System will be a configuration of men, machines, methods, data, and facilities designed to satisfy the informational needs of the community. In such a system, men and machines combine to perform the function data communications, processing, storage, and display associated with the inquiries and delivery of information to the subscribers. This interchange of information takes place for purposes relating to education, cultural interchange, health care delivery, religion, business, recreation, and many others.

In creating and developing the Community Information System in Jonathan/Chaska, the existence of four major forces must be recognized due to their influence on the types of services which may be offered:

- Technical Forces
- Economic Forces
- Legal/Political Forces
- Socio-cultural Forces

The technical and economic forces were the significant forces when CATV first entered rural areas. Today there are also certain limitations on the technical capabilities in terms of the advancement into the two-way cable field as to what is feasible as well as economically practical to provide. Since we are considering "the right" to information, economic divisions must be designed to give this information to all income levels and, at the same time, maintain a profitable company.

When the CATV industry moved into the urban environment, the legal/political forces became significant. In a CIS, these factors are even more paramount; as managers of computer banks containing information, in some cases, highly personal information, control must be designed to provide limited access to certain information. Such privacy of information incorporates the legal/political factors as a major influence on the development of the Community Information System.

Considerations in the socio-cultural area lean toward determining the appropriate types of information to be made available to the community in support of activities such as education, health care, and community interests. A Community Information System by its nature in serving the informational needs of the community must consider and respond to the socio-cultural forces present as well as the technical, economic, and legal/political aspects.

The program at Jonathan, Minnesota, sponsored by the U.S. Department of Housing and Urban Development is directed toward gaining more knowledge about how communications, more specifically, two-way cable communications, can serve the socio-cultural needs in the community.

Emphasis up to now has been on informing the public of the two-way technology and citing estimates of the various services that can be provided. The focal point should trend toward what people in these communities feel is important in the way of communications and what they view as significant services to satisfy their personal and professional lives.

In Jonathan, the overall program is divided into three phases as shown in Figure 2. The first phase deals with the basic data and information necessary to guide the development, construction, and operation of a Community Information System. In Phase II, plans include the design, construction, and operation of a 100-terminal network in nearby neighborhoods connecting homes, businesses, and institutions to the system. This can serve as a prove-in phase for both hardware and software. Keeping the network to this size will allow a manageable system, yet one adequate to provide valuable data. It is expected Phase II will require 1 to 1½ years. Phase III will be designed to offer a variety of services to the entire community of Jonathan and Chaska. Based on the findings and results of Phases I and II, this third phase will provide meaningful services to the community on a paying basis over a period of 2½ to 3 years, obtaining data relative to subscriber desires, willingness to pay, and cable communications as a vehicle for providing total communications as a way to improve the socio-cultural elements of the community.

In each of these phases, a primary objective will be to gather demand-side data and information to project cost benefits of various services. A multi-phase program of this type provides an optimum approach for gaining knowledge, experience and preparing the community for this technology as it becomes available.

In these activities, one of the most challenging tasks has been to develop the methods for determining individual preferences and values concerning two-way cable services. Four techniques are being used for eliciting significant data about such preferences and values; they are as follows:

(1) In an effort to determine the services which individuals consider functional, visitors to the demonstration center are asked to complete a short questionnaire, either the standard form for adults or the simpler form for children.

(2) Each machine and program in the demonstration center is being connected to an automatic counter, giving us data on how often each one is used.

(3) People of the Jonathan/Chaska community are participating in panel discussions led by our program's consulting behavioral scientists. They take part in a series of opinion surveys dealing with the contributions of two-way cable communications to the quality of life.

(4) A sample of the general population of the area will also be interviewed in some depth regarding the preferences for cable communication systems and the monetary value the services maintain for them.

These four methods for getting demand-side data have not yet been underway long enough to provide any figures that would be meaningful to our discussion here today, but these figures will be part of our report to the U.S. Department of Housing and Urban Development later this year.

Let me give you some ideas of what the visitor sees and does at the Community Information Systems Demonstration Center. A plan view of this demonstration facility is shown in Figure 3. The visitor enters the demonstration center after having gone through the Jonathan Development Corporation's information area and been introduced to the new town and its goals. After being greeted by our hostess, the visitor's attention is drawn to an explanation of how a Community Information System is a community service based upon a high level of participation by the citizenry in determining the particular kinds of services that can be provided (Figure 4). Different elements of the community affected by cable communications are illustrated visual-graphically by a large scale map which initiates some idea of the geographic area that can be served by this project.

A 10-minute slide/tape presentation then points out how important this new type of communication system may be and explains to the visitor how he may use the two-way cable system present in the demonstration center. He previously noticed the Communication Center equipment (Figure 5); it may have aroused his curiosity with its visual displays indicating how various groups of lights have something to do with intrusion, fire, no response, and other functions. Practical usage of the hands-on equipment of the Communication Center is an alluring area of the display. Here, the visitor may use the "Responsor"tm to call up the desired program sequence. Figure 6 shows a listing of the programs available and those soon to be available. One program, for example, shows the interactive system at work in education. This program offers some basic facts about the first three planets of the solar system and then asks the viewer a series of questions, proceeding on to the next question only after he gives the correct answer. The key element of this type of programming is the General Electric AVR-10 which has been extended beyond its original usage to operate with the interactive cable system for testing the understanding of information given and for collecting answers from the viewer. As he continues through the center, the visitor comes to a simulated home setting where the "Responsor"tm system once again is available to him to demonstrate the manner in which the system can be used to provide fire and intrusion protection 24 hours a day. It provides a fail-safe feature with a loss of communication signal at the Communication Center if any response unit fails to answer its interrogation signal.

In this system, each "Responsor"tm at a subscriber station (Figure 7) is assigned a unique digital address. At the time each "Responsor"tm is polled (every 10-20 seconds), the particular "Responsor"tm can either accept data or transmit data. The "Responsor"tm units for this demonstration have the ability to store and display four characters. This capability can be extended to include more characters by expanding the capacity of the local buffer storage element in the "Responsor"tm unit.

This system also has the ability to communication between individual "Responsors"tm on the network; for example, "Responsor"tm #1 can transmit data to "Responsor"tm #5 or the reverse simply by calling up the desired station and receiving back a confirming signal indicating that the station is available to receive data. The system is designed so that it can provide various polling rates, depending on the type of service desired. These rates can vary from scanning once every 10 seconds to several times a second. For example, if a station wishes to type a message, the scanning rate could be increased to 10 scans per second which would allow the transmission of approximately 40 characters per second.

In the idle mode, the system is continually scanning each "Responsor"tm. These "Responsors"tm are designed to accept sensor inputs at all times for such things as fire intrusion. Therefore, each time a station is polled, the return idle message from each unit indicates at the message center the status of alarms. Of course, this same process can apply for performance monitoring of the cable network itself.

This presentation has given a brief description of the demonstration facility at Jonathan and the system capability. For more information, please write or visit us at Community Information Systems, Inc., Jonathan Village Center, Chaska, Minnesota 55318.

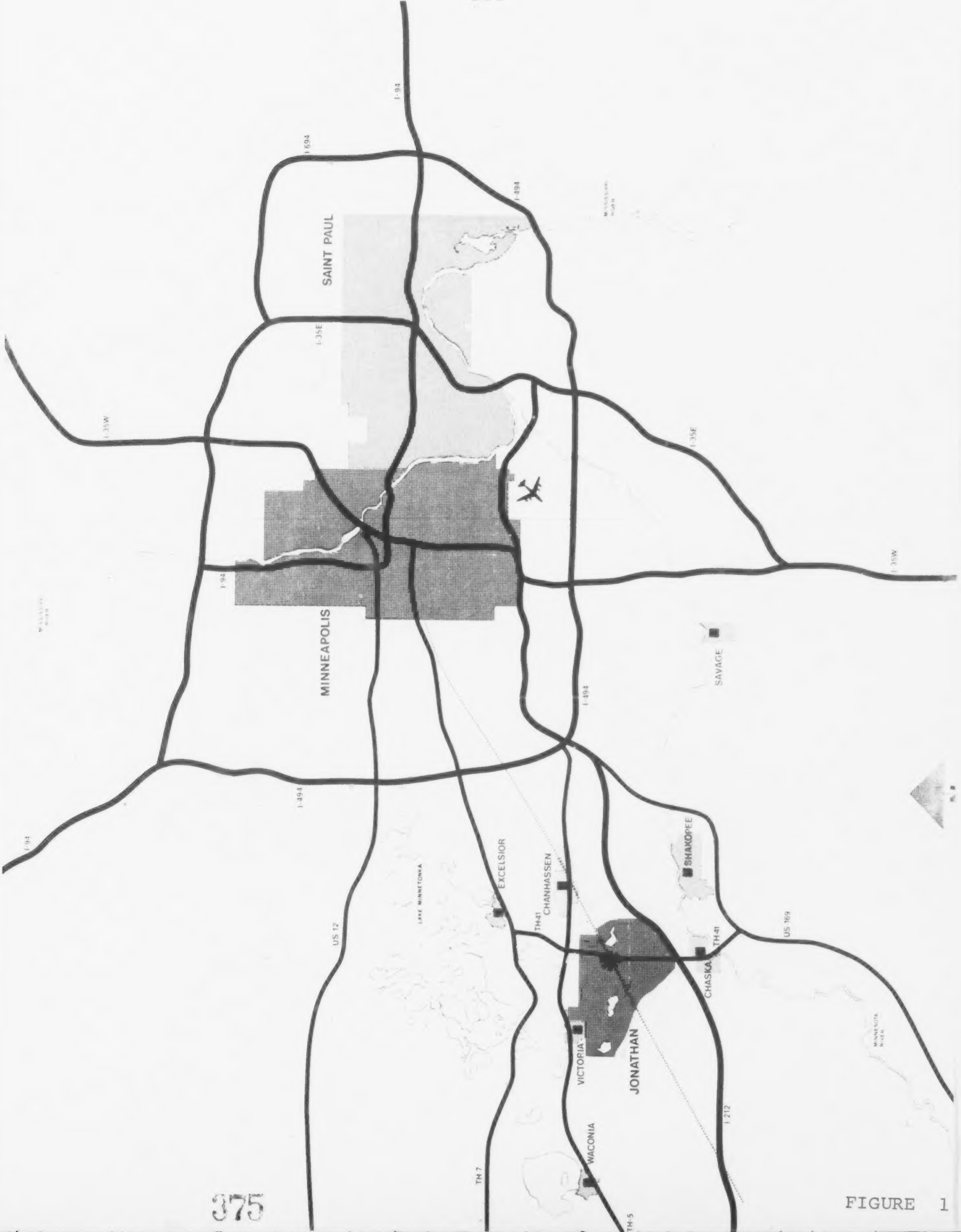
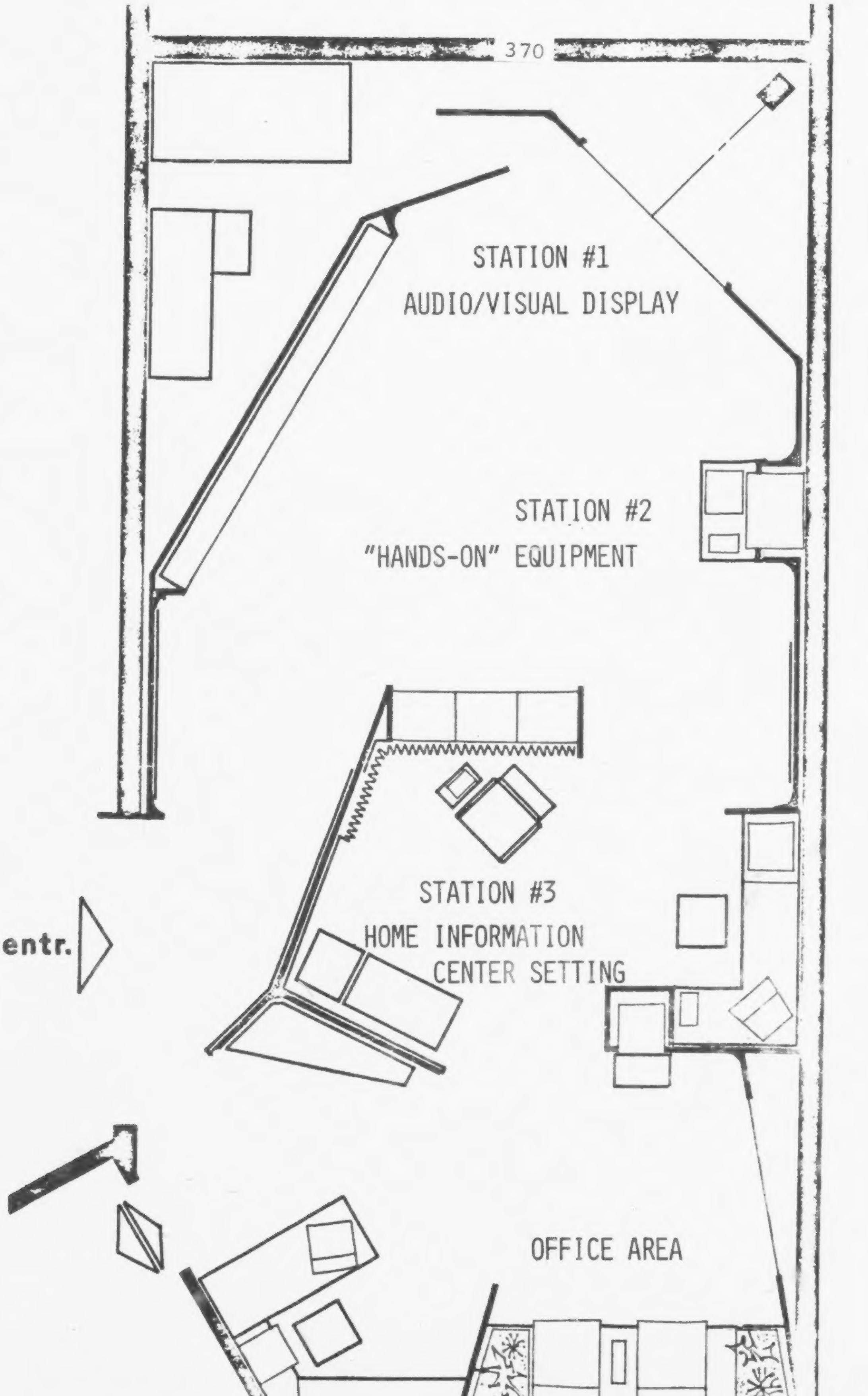

SAINT PAUL
MINNEAPOLIS
SAVAGE
SHAKOPEE
CHASKA
CHANHASSEN
EXCELSIOR
VICTORIA
JONATHAN
WACONIA
LAKE MINNETONKA
MINNESOTA RIVER
I-94
I-694
I-494
I-35E
I-35W
US 12
US 169
TH 41
TH 7
TH-5
I-212

FIGURE 1

PHASES OF THE EXPERIMENT.

1 • Design, construct, and operate a C.I.S. Demonstration Center
  • Define the follow-on experiment
2 • Design, construct, and operate a 100-terminal network in nearby neighborhoods
3 • Modify and extend the two-way network to 1500 terminals in Jonathan-Chaska
& (In each phase) • Get demand-side data
  • Analyze benefit cost.

FIGURE 2


370
STATION #1
AUDIO/VISUAL DISPLAY
STATION #2
"HANDS-ON" EQUIPMENT
STATION #3
HOME INFORMATION
CENTER SETTING
entr.
OFFICE AREA

CIS DEMONSTRATION AREA

FIGURE 3

FIGURE 4

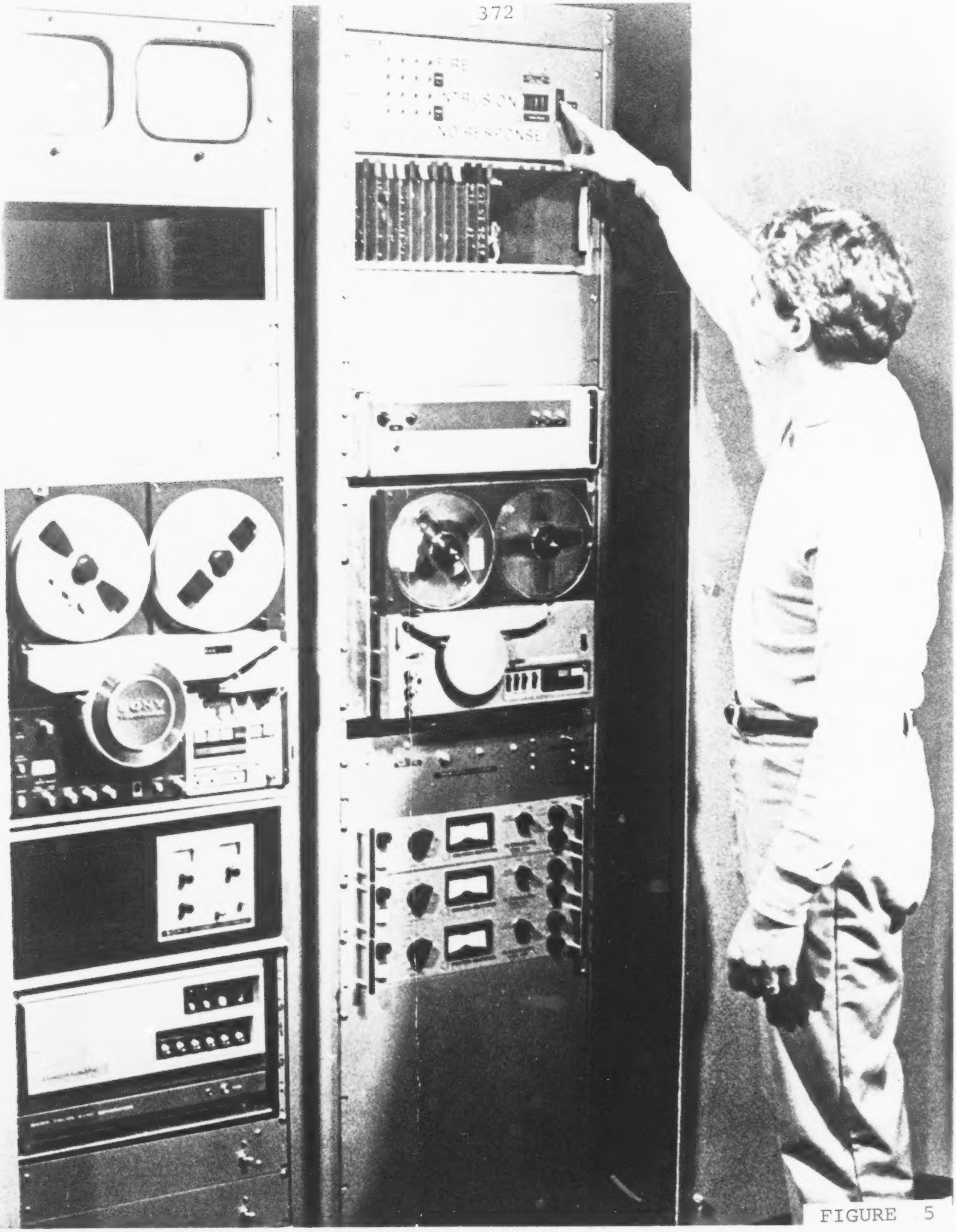
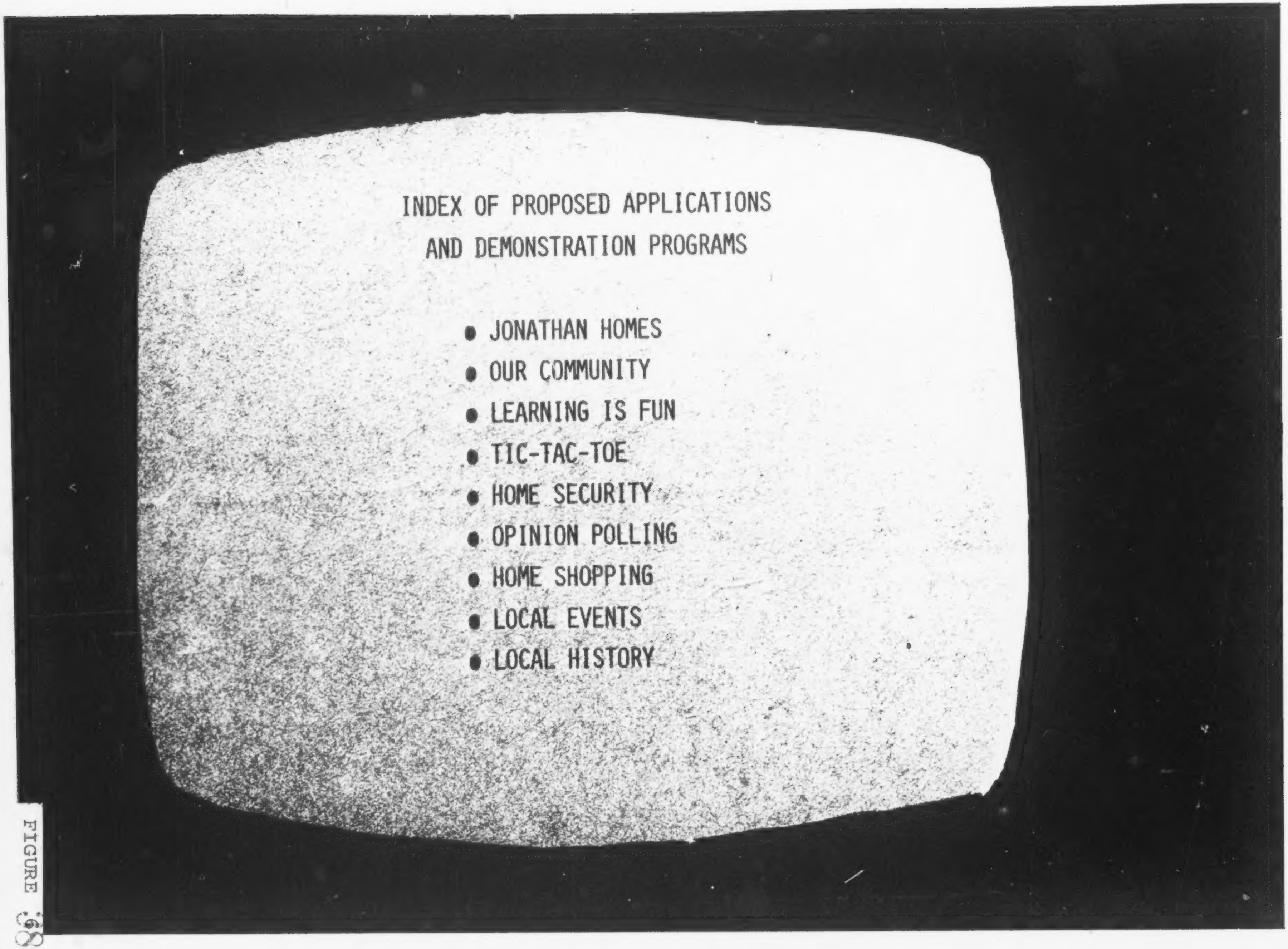

FIRE
INTRUSION
NO RESPONSE
SONY

FIGURE 5



INDEX OF PROPOSED APPLICATIONS
AND DEMONSTRATION PROGRAMS

- JONATHAN HOMES
- OUR COMMUNITY
- LEARNING IS FUN
- TIC-TAC-TOE
- HOME SECURITY
- OPINION POLLING
- HOME SHOPPING
- LOCAL EVENTS
- LOCAL HISTORY

FIGURE 6

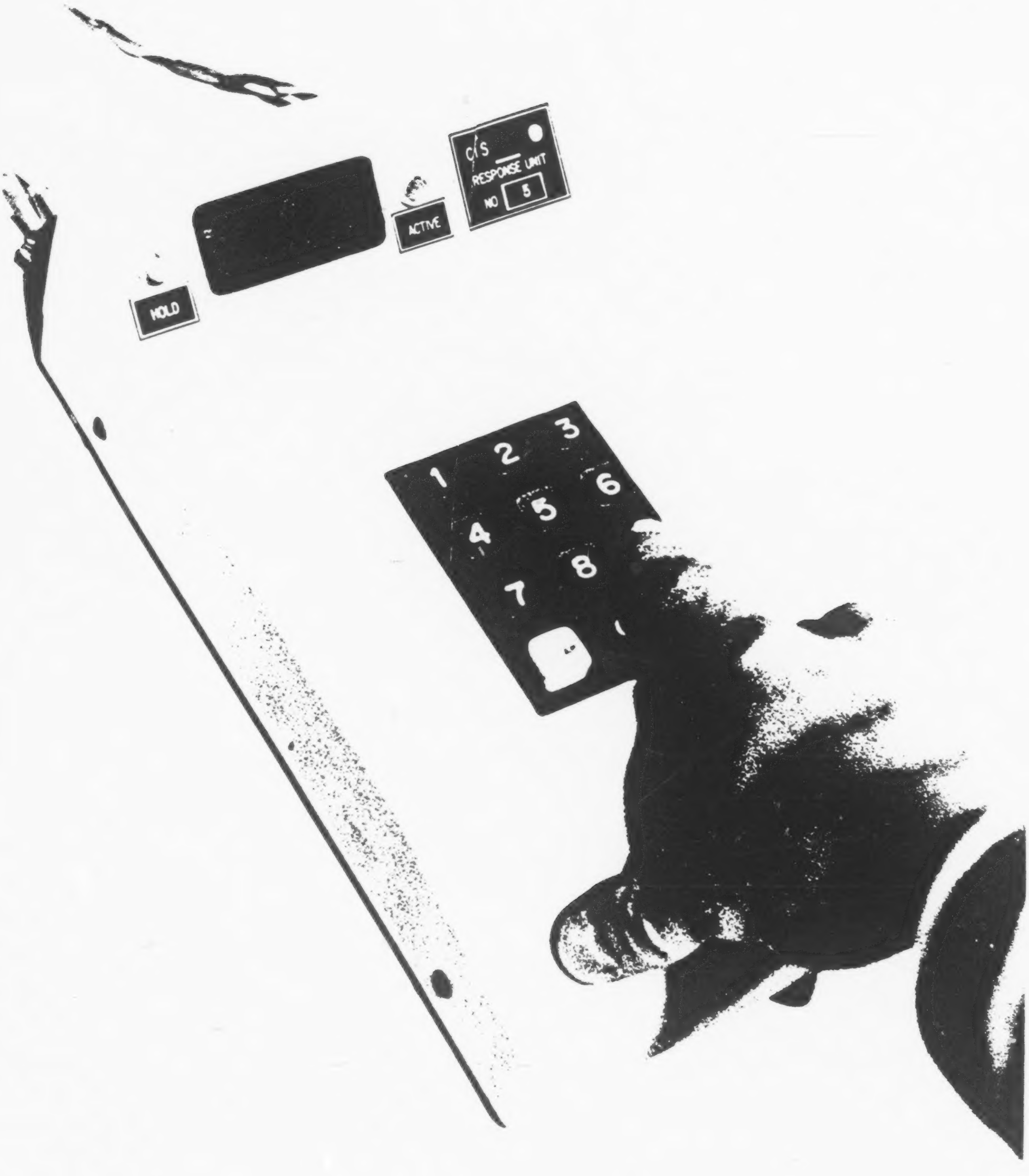

C/S
RESPONSE UNIT
NO 5
ACTIVE
HOLD
1
2
3
4
5
6
7
8

FIGURE 7

TWO-WAY EXPERIENCE WITH DIAL-A-PROGRAM AT DENNIS PORT

By R.P. Gabriel, B.Sc., FIEE, MIEEE, Chairman,
Rediffusion International Limited

In the hub type network of Dial-a-Program the requirement for two-way transmission of data, voice or vision is met in a very simple and straight forward manner. Indeed, Dial-a-Program is potentially a complete communication network carrying not only television programs in the ordinary sense but telephone and full band width picturephone as well. Figure 1 shows the general arrangement for the distribution of television programs. Subscribers select their desired program from those available at the program exchange by remote control. All vision signals are carried in the channel 3-9 MHz on identical phase locked carriers. Each subscriber is connected to the exchange by means of two balanced pairs in a multipair cable of special construction known as Qwist(TM). A cross section of these two pairs is shown in Figure 2 where a comparison is also given of the three pairs of telephone cable which are required for the narrow band picturephone service. The larger pair in the Qwist unit carries the television program and the smaller pair, which has a usable band width up to about 3 MHz, may be used in various ways. In the simplest case it is used only for the control signals which operate the selector switch in the exchange.

Two-way for Voice

The next step is to use it also for telephone purposes as is being done in the Dial-a-Program system now being installed in the Health Sciences Communications Center of Case Western Reserve University at Cleveland, Ohio. A change-over relay is fitted both at the subscriber and exchange ends of the smaller pair, which simply transfers the circuit to the telephone instrument at the subscriber's end and the internal telephone exchange at the other end whenever the circuit is not being used for the control of the vision selector switches. The transfer is automatic and vision selection is given priority so that as soon as the dial is moved off normal for vision selection the circuit is transferred for the purpose. The arrangement is shown in Figure 3.

Sharing the circuit in this way for one purpose or the other is quite satisfactory in many cases, particularly where the telephone is being used as an adjunct to the television pictures in an educational situation such as that at Case Western Reserve University. In other circumstances, for example where Dial-a-Program is used as a universal communications network in a new community, such sharing would be unacceptable and the smaller pair can be allocated exclusively to the telephone. At some slight additional cost the control signals for the vision selector switch can be combined with the vision signals on the larger pair and this has been on demonstration on one subscriber's connection at Dennis Port.

The community network might then be arranged as in Figure 4. The diagram shows the telephone pairs as taken right back to a conventional telephone exchange but the layout fits in well with proposals to use digital signals for the telephone. Conversion to digital form can conveniently be carried out at the wide band program exchanges and the telephone signals for a group of subscribers can be concentrated together and then carried over a single circuit in the wide band trunk routes. Combination of the two services, telephone and cable television, in this way does, of course, have a very favourable effect on the economics.

Two-way for Vision

The larger pair in the Qwist unit is usable up to about 16 MHz without too much difficulty from crossview. As the 3 to 9 MHz is used for outward transmission of vision signals, this leaves the channel 9 - 16 MHz available for inward transmission. Since in the ordinary way there are no amplifiers between the exchange and the subscriber, one may go to any outlet on the system and plug in a camera or other source, modulate the signal on to 16 MHz carrier and send it back to the exchange.

At the exchange the return signals are separated out by high and low pass filters, their frequency is changed to the standard 3 - 9 MHz channel and they are then available for application like any of the other signals, to one of the exchange bus-bars and for transmission over one circuit in the multi-coaxial cable which forms the trunk route between exchanges. Where the number of subscribers requiring to use the two-way vision facility simultaneously is few, problems with crossview, due to beats between their respective carriers will be unlikely to arise and it is sufficient to use a reasonably stable oscillator as the carrier source and a demodulator-modulator at the exchange end. This is the arrangement, which has been on demonstration for the past year at Dennis Port, Cape Cod, is shown as a block diagram in Figure 5. The sound signal generated at the subscriber's premises may be carried in various ways but the simplest is to send it back using the audio frequency base band as shown in Figures 5 and 6.

When it is probable that two subscribers whose circuits are contained within the same 6 Qwist cable will require two-way transmission at the same time, then it is necessary that their carriers should be locked together. To achieve this the arrangement shown in Figure 6. is adopted. The master oscillator which we will assume for the moment is located at the local exchange, provides the carrier at roughly 8 MHz which is used for all outgoing channels. A tapping is taken from this source and the frequency divided by four to give a signal at about 2 MHz which is filtered to get rid of harmonics and applied to a hybrid transformer unit which is plugged into the subscriber's circuit when he requires two-way transmission. The 2 MHz pilot signal is sent out over the larger pair of the Qwist being multiplexed with the go and return vision signals also on that pair. At the subscriber's end the 2 MHz pilot is filtered and out multiplied by eight to give the return signal carrier at 16 MHz approximately.

When this signal is received at the exchange it is mixed with the third harmonic of the 8 MHz master oscillator to give a 40 MHz intermediate frequency and this in turn is mixed with the harmonic and a modulated 8 MHz signal results which is phase locked to the other channels and is ready after amplification for application to one of the bus-bars. Equipment operating on this principle will be installed later this year at Case Western Reserve University.

REDIFFUSION DIAL-A-PROGRAM LOCAL DISTRIBUTION NETWORK FOR TV GENERAL ARRANGEMENT

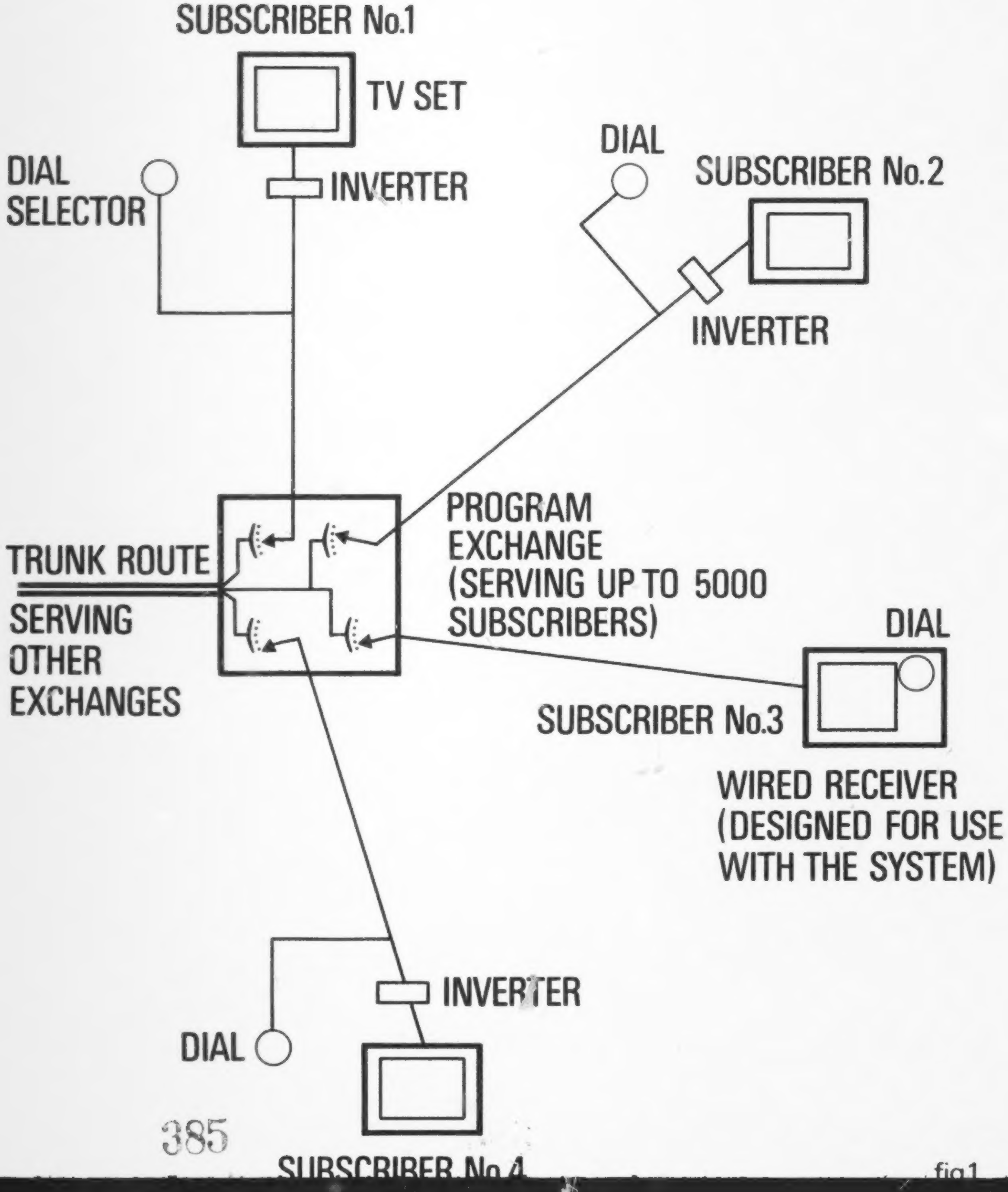
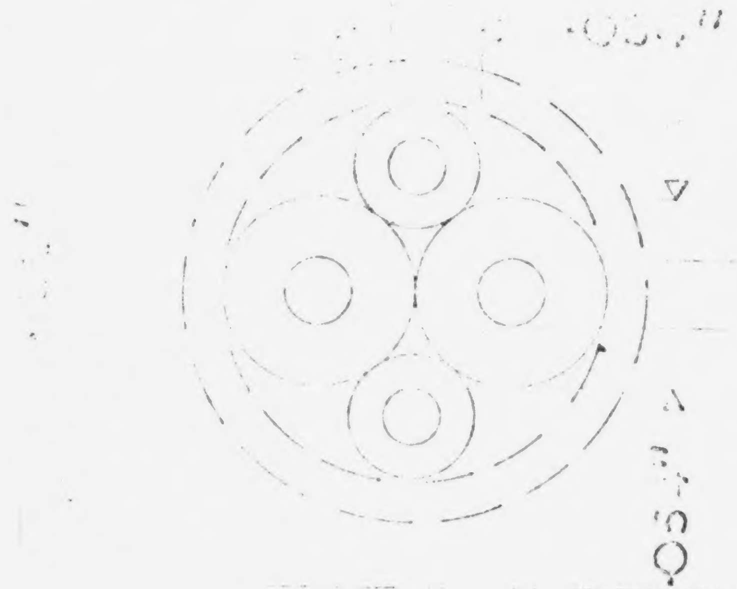

SUBSCRIBER No.1
TV SET
DIAL SELECTOR
INVERTER
DIAL
SUBSCRIBER No.2
INVERTER
PROGRAM EXCHANGE (SERVING UP TO 5000 SUBSCRIBERS)
TRUNK ROUTE
SERVING OTHER EXCHANGES
DIAL
SUBSCRIBER No.3
WIRED RECEIVER (DESIGNED FOR USE WITH THE SYSTEM)
INVERTER
DIAL
SUBSCRIBER No.4

fig1

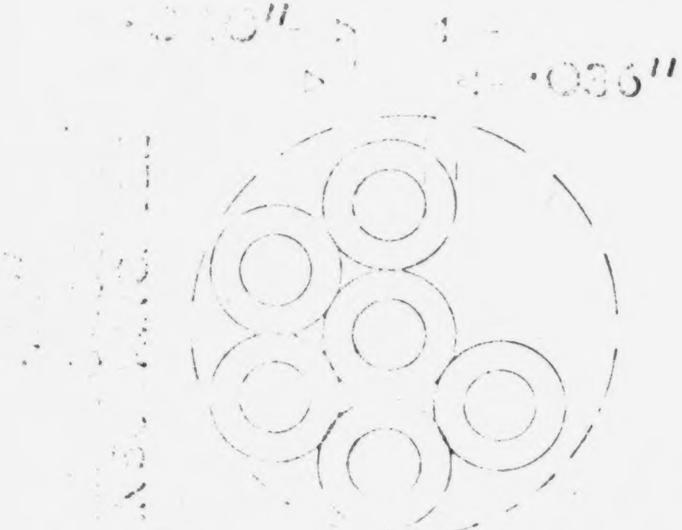


[illegible] CABLE

USABLE UP TO 15MHz.

ATTENUATION 1·5dB/100FT.
AT 10MHz

PRICE AS 1/6 PART OF
SCREENED 6 QUIST (12 PAIR
CABLE) CA 165 [illegible] CENTS/FT.



BRITISH POST OFFICE
TELEPHONE CABLE CW1300.

3 PAIRS AS USED FOR
VIDEOPHONE.

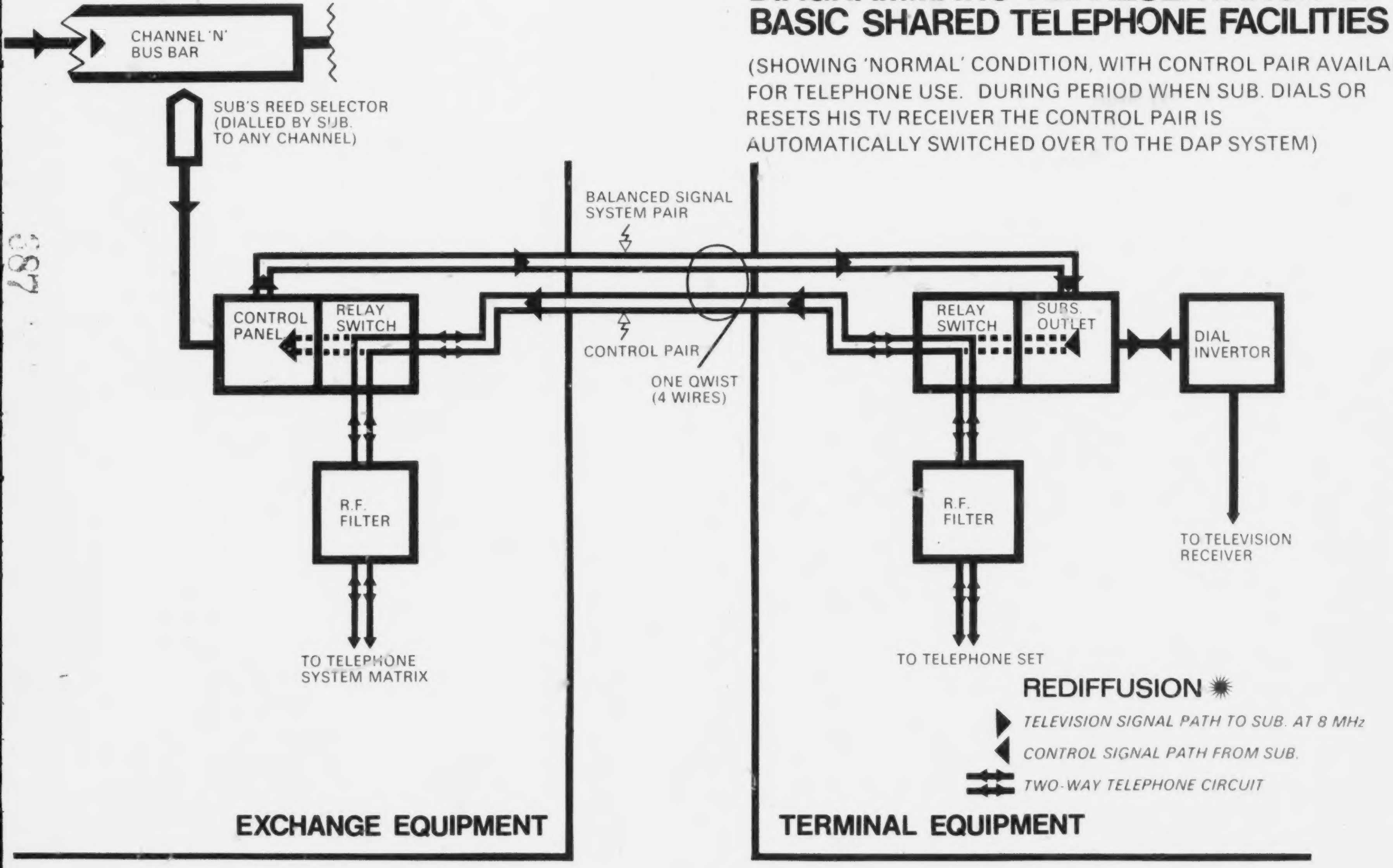
PRICE AS 3/7 OF SCREENED
7 PAIR CABLE 1·9 CENTS/FT. OR
AS 3/50 OF SCREENED 50 PAIR
CABLE [illegible] CENTS/FT.

CABLE CROSS SECTIONS AND PRICES (CONCLUDED)

Fig. 2.

DIAGRAMMATIC REPRESENTATION OF BASIC SHARED TELEPHONE FACILITIES

(SHOWING 'NORMAL' CONDITION, WITH CONTROL PAIR AVAILABLE FOR TELEPHONE USE. DURING PERIOD WHEN SUB. DIALS OR RESETS HIS TV RECEIVER THE CONTROL PAIR IS AUTOMATICALLY SWITCHED OVER TO THE DAP SYSTEM)


CHANNEL 'N' BUS BAR
SUB'S REED SELECTOR (DIALLED BY SUB. TO ANY CHANNEL)
CONTROL PANEL
RELAY SWITCH
R.F. FILTER
TO TELEPHONE SYSTEM MATRIX
BALANCED SIGNAL SYSTEM PAIR
CONTROL PAIR
ONE QWIST (4 WIRES)
RELAY SWITCH
SUBS. OUTLET
DIAL INVERTOR
R.F. FILTER
TO TELEPHONE SET
TO TELEVISION RECEIVER
REDIFFUSION
▶ TELEVISION SIGNAL PATH TO SUB. AT 8 MHz
◀ CONTROL SIGNAL PATH FROM SUB.
⇄ TWO-WAY TELEPHONE CIRCUIT
EXCHANGE EQUIPMENT
TERMINAL EQUIPMENT

387

REDIFFUSION DIAL-A-PROGRAM ARRANGEMENT FOR COMBINED WIDE & NARROW BAND TWO WAY SWITCHED NETWORK

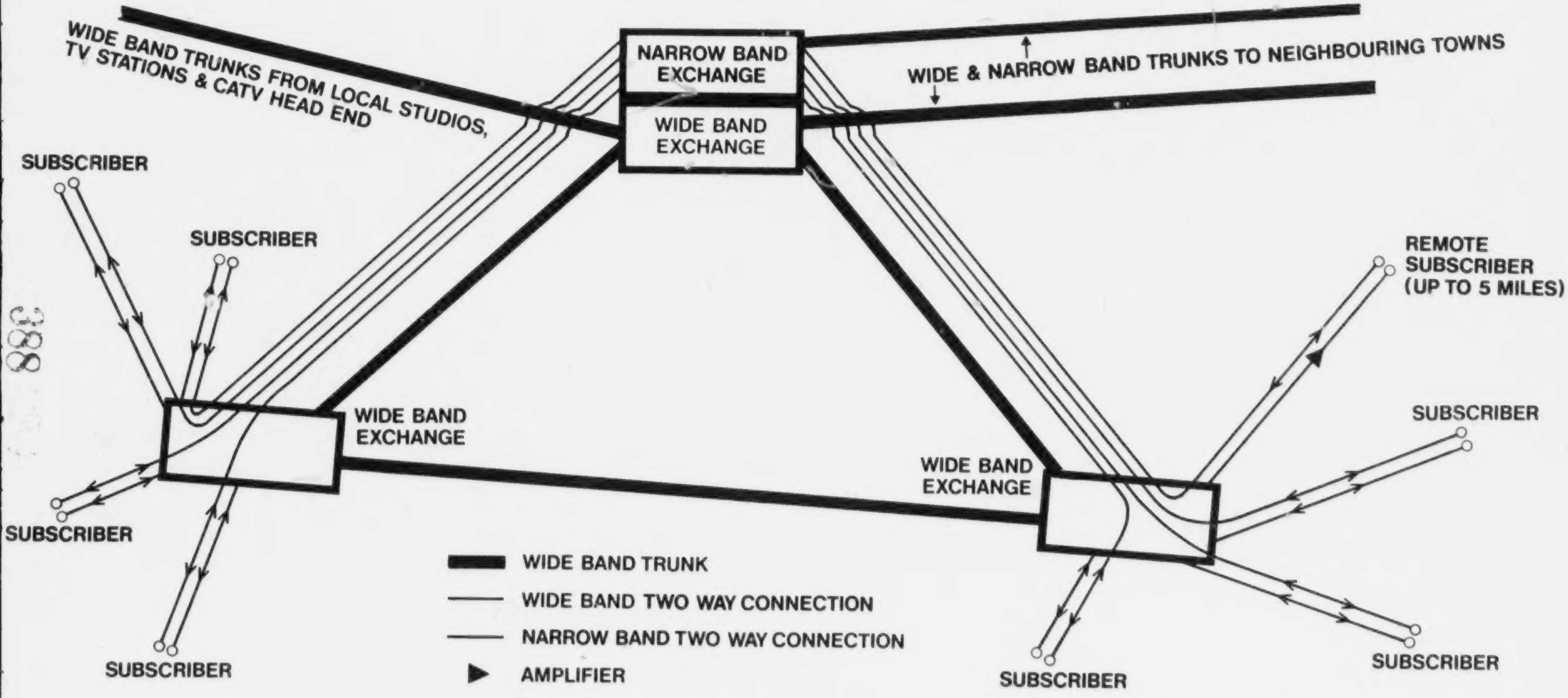

WIDE BAND TRUNKS FROM LOCAL STUDIOS, TV STATIONS & CATV HEAD END
NARROW BAND EXCHANGE
WIDE BAND EXCHANGE
WIDE & NARROW BAND TRUNKS TO NEIGHBOURING TOWNS
SUBSCRIBER
SUBSCRIBER
SUBSCRIBER
SUBSCRIBER
WIDE BAND EXCHANGE
REMOTE SUBSCRIBER (UP TO 5 MILES)
SUBSCRIBER
WIDE BAND EXCHANGE
SUBSCRIBER
SUBSCRIBER
WIDE BAND TRUNK
WIDE BAND TWO WAY CONNECTION
NARROW BAND TWO WAY CONNECTION
AMPLIFIER

Fig. 4

DIAGRAMMATIC REPRESENTATION OF PROTOTYPE TWO-WAY SYSTEM IN USE IN DENNIS PORT, MASS.

(SHOWING SUBSCRIBER MONITORING HIS OWN SIGNAL FROM HIS ALLOCATED BUS-BAR CHANNEL)

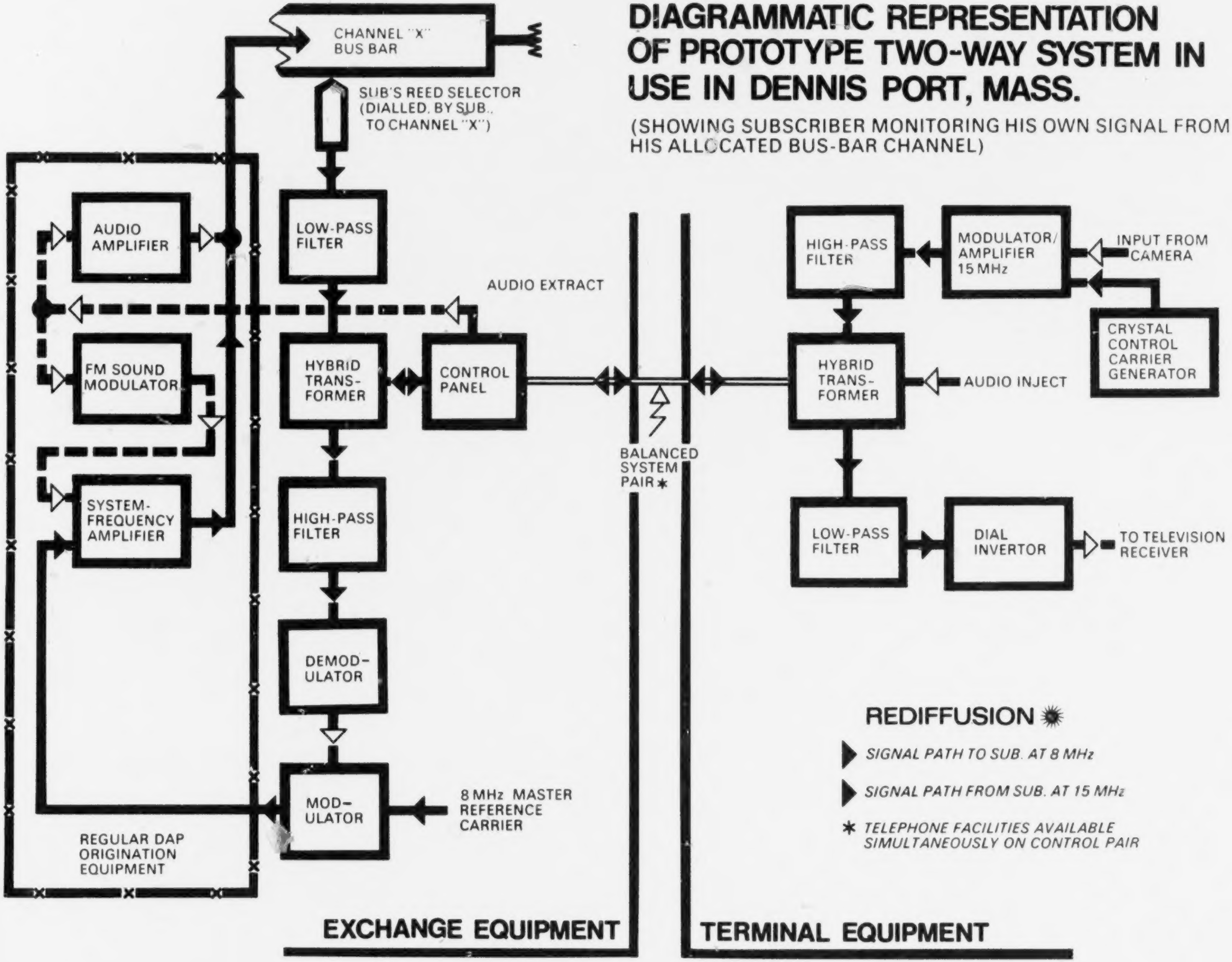
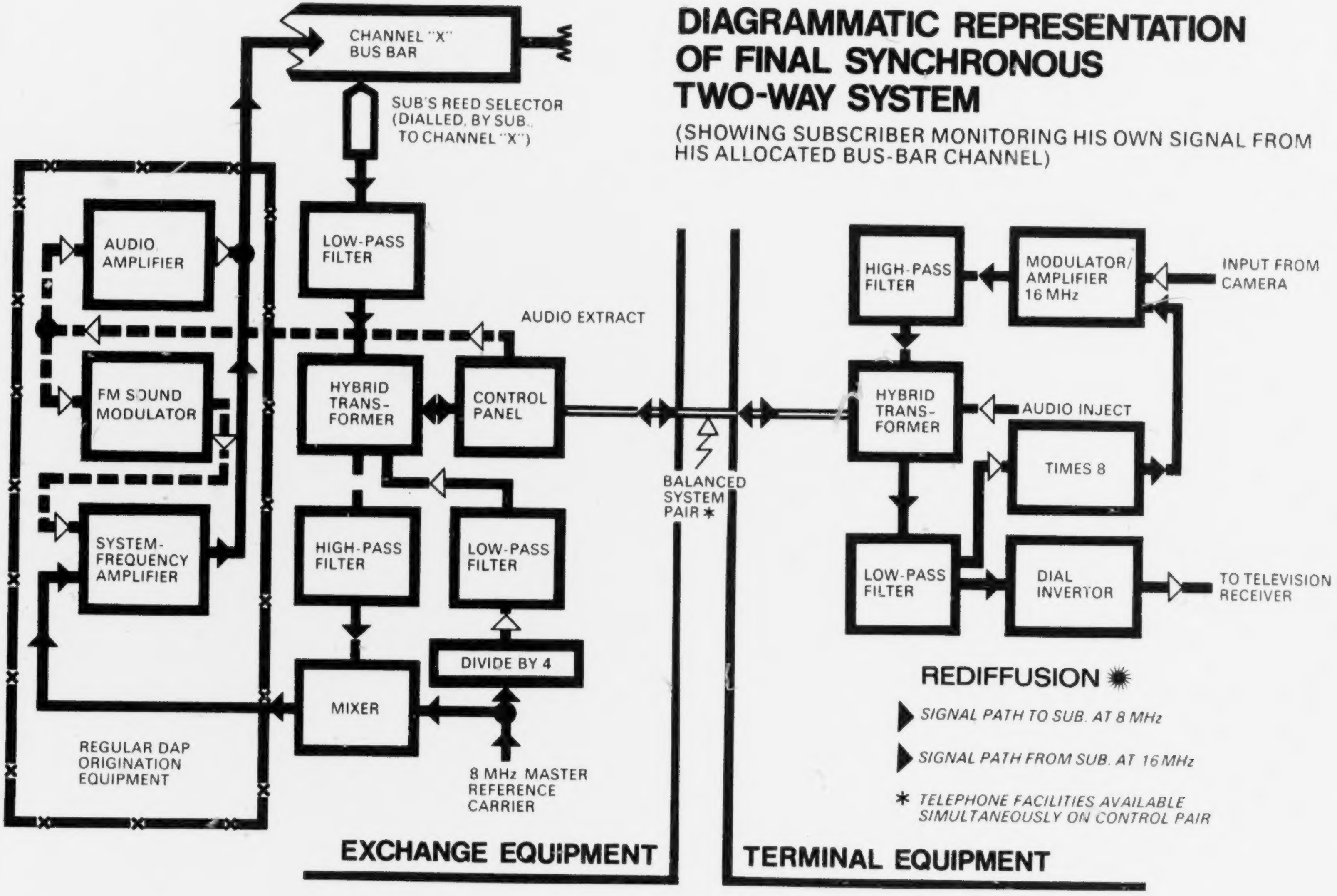

CHANNEL "X" BUS BAR
SUB'S REED SELECTOR (DIALLED, BY SUB., TO CHANNEL "X")
AUDIO AMPLIFIER
LOW-PASS FILTER
AUDIO EXTRACT
FM SOUND MODULATOR
HYBRID TRANS-FORMER
CONTROL PANEL
SYSTEM-FREQUENCY AMPLIFIER
HIGH-PASS FILTER
DEMOD-ULATOR
MOD-ULATOR
8 MHz MASTER REFERENCE CARRIER
REGULAR DAP ORIGINATION EQUIPMENT
BALANCED SYSTEM PAIR *
HIGH-PASS FILTER
MODULATOR/ AMPLIFIER 15 MHz
INPUT FROM CAMERA
CRYSTAL CONTROL CARRIER GENERATOR
HYBRID TRANS-FORMER
AUDIO INJECT
LOW-PASS FILTER
DIAL INVERTOR
TO TELEVISION RECEIVER
REDIFFUSION
SIGNAL PATH TO SUB. AT 8 MHz
SIGNAL PATH FROM SUB. AT 15 MHz
* TELEPHONE FACILITIES AVAILABLE SIMULTANEOUSLY ON CONTROL PAIR
EXCHANGE EQUIPMENT
TERMINAL EQUIPMENT

FIG. 5.



DIAGRAMMATIC REPRESENTATION OF FINAL SYNCHRONOUS TWO-WAY SYSTEM

(SHOWING SUBSCRIBER MONITORING HIS OWN SIGNAL FROM HIS ALLOCATED BUS-BAR CHANNEL)

CHANNEL "X" BUS BAR
SUB'S REED SELECTOR (DIALLED, BY SUB., TO CHANNEL "X")
AUDIO AMPLIFIER
FM SOUND MODULATOR
SYSTEM-FREQUENCY AMPLIFIER
REGULAR DAP ORIGINATION EQUIPMENT
LOW-PASS FILTER
HYBRID TRANS-FORMER
CONTROL PANEL
AUDIO EXTRACT
HIGH-PASS FILTER
LOW-PASS FILTER
DIVIDE BY 4
MIXER
8 MHz MASTER REFERENCE CARRIER
BALANCED SYSTEM PAIR *
EXCHANGE EQUIPMENT
TERMINAL EQUIPMENT
HIGH-PASS FILTER
MODULATOR/ AMPLIFIER 16 MHz
INPUT FROM CAMERA
HYBRID TRANS-FORMER
AUDIO INJECT
TIMES 8
LOW-PASS FILTER
DIAL INVERTOR
TO TELEVISION RECEIVER
REDIFFUSION
SIGNAL PATH TO SUB. AT 8 MHz
SIGNAL PATH FROM SUB. AT 16 MHz
* TELEPHONE FACILITIES AVAILABLE SIMULTANEOUSLY ON CONTROL PAIR

FIG. 6.

SRS EL SEGUNDO INTERIM TEST REPORT

Richard T. Callais
Manager, SRS Division
Theta-Com of California
Los Angeles, California

INTRODUCTION AND SUMMARY

This paper is presented as a progress report on the interim testing of the Subscriber Response System (SRS), in preparation for the field installation at El Segundo.

This first phase of the overall test plan includes tests made at Theta-Com using actual two-way cable cascades, a two-way AML microwave link, and the prototype SRS terminals which will be used at El Segundo.

Data taken in these tests indicate the performance of the full SRS system in operation with a 16-amplifier cascade are substantially error free in the presence of typical or even excessive thermal noise. Excellent performance was also obtained in the presence of simulated impulse noise and interfering CW carriers.

The factors which are important in the design of an interactive system including the oft-neglected computer and its software complement are discussed. The results of tests simulating heavy service traffic show the SRS system can respond in seconds to such traffic, including the recording of billing information on magnetic tape.

Finally, the services which will be tested at El Segundo are categorized and discussed.

THE SRS SYSTEM

The SRS system is a two-way interactive system, the basic operation of which is illustrated in Figure 1.

The two-way interactive communication takes place between a computer complex termed the Local Processing Center (LPC), shown in Figure 2, and subscriber terminals located in the home or business location. The subscriber terminals consist of two basic units - a Modem, shown in Figure 3, and a Subscriber Console.

The Modem unit contains no operating controls and can be located behind the television set or in some other relatively nearby, unobtrusive location.

The Subscriber Console is connected to the Modem by a small diameter cable (nominally a maximum of 50 feet in length) and is intended to be located within view of the television set. Two models of the Subscriber Console are currently available. The SRS Model 101, shown in Figure 4, contains a simple 3-digit keyboard. The SRS Model 102, shown in Figure 5, has a full 0 to 9 numeric keyboard and a strip printer. A paper tape cartridge used in conjunction with the strip printer is shown in Figure 6.

The units shown are operating samples from the prototype production run of 30 terminals.

More detail describing the basic SRS system is available in Reference [1].

EL SEGUNDO TEST PLAN

Starting in late spring of this year, the Theta-Com SRS system will be tested on a Theta-Cable two-way CATV installation now nearing completion in the City of El Segundo, California.

Initial testing will be performed with 30 of the prototype SRS terminals and will be continued and extended with the production and installation of 1,000 pre-production terminals starting at the end of 1972.

The initial tests using 30 terminals will combine technical testing and demonstrations and development of the services offered. These studies will continue as the 1,000 units are installed and will phase into the sale of actual services.

EL SEGUNDO CABLE SYSTEM

The CATV system being installed in El Segundo by Theta-Cable is a two-cable system, shown in Figure 7[1]. The system consists of an "A" cable system and a "B" cable system. The "A" cable trunk line is intended for downstream transmission only in the band from 54 to 300 MHz. The "B" trunk line operates bi-directionally: downstream from 174 to 300 MHz, and upstream from 5 to 108 MHz. The "A" cable distribution system, however, operates bi-directionally with the upstream bandwidth between 5 and 30 MHz. Upstream signals from "A" distribution line are routed through appropriate low pass filters to the "B" trunk where they travel upstream to the head end and are routed to the SRS Local Processing Center. The "A" trunk, and distribution system, is intended primarily for home subscribers while the "B" trunk is intended for municipal, business, and industrial usage, where the greater upstream bandwidth (5-108 MHz) can be utilized for additional data communication and/or upstream video channels.

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[1] Diagram furnished by Mr. Thomas H. Ritter, TelePrompTer Corporation.

The "A" cable system will contain 32 trunk amplifiers and 124 line extenders. The "B" cable system will contain 32 trunk amplifiers and only 4 line extenders, in view of the smaller distribution demand anticipated from the specialized users.

The longest cascade in the system consists of 7 trunk amplifiers and 2 line extenders. Total plant mileage is approximately 30 miles. For the trunk, 3/4" foam dielectric cable will be used and 1/2" cable for the distribution system.

TESTS IN PROGRESS

While the El Segundo cable system construction is nearing completion, extensive testing of the SRS system using actual cable cascades is in progress at the Theta-Com plant. This testing and other developmental efforts will continue at Theta-Com using a second LPC following installation of the present LPC in El Segundo.

DUAL CABLE TESTS

A two-way two-cable system, representative of the El Segundo installation, has been assembled at the Theta-Com facility in Los Angeles. The cable cascade is shown in Figure 8 installed in a large temperature chamber where it has been extensively tested. Reels of aluminum sheath cable similar (except for smaller diameter) to the actual trunk cable are used to provide a 20 dB spacing measured at 300 MHz between amplifiers. Sixteen downstream amplifiers are used in the "A" trunk system and sixteen two-way amplifiers are employed in the "B" cable trunk.

For the El Segundo system, Jerrold SP-1/2/5-2W trunk amplifiers and SLE-300-2W line extenders are used.

While testing of this system is still underway, some initial results can be reported at this time.

Tests were made using an SRS 101 terminal and the full LPC computer complex feeding the aforementioned cascaded cable system. During the tests, 12 channels of video were being carried over the cable, plus the FM band. Computer controlled operation of all of the basic services, including channel selection, channel polling, meter reading, opinion polling, premium and restricted TV control, accessory power control and emergency alarms were repeatedly demonstrated satisfactorily.

Tests are also being conducted to determine two-way system error performance. For these tests, a special LPC computer program was written to control the transmission of downstream commands such that four different commands were sent to an SRS terminal in sequence and the cycle was repeated indefinitely. In response to each of these commands, the terminal transmitted upstream different responses in accordance with the downstream command. These tests were performed using the 16-amplifier dual cable cascade.

The computer compared the responses to each command with the normal response expected and periodically read out to a teletype the total number of errors and the type of error. Over a period of 11 hours during which approximately 40 million complete two-way transmissions, comprising a total of 2.5 billion bits, were made with no errors. This error value corresponds to a bit error rate of 4×10^{-10} if we assume the next transmission (after the end of the actual test) were to contain an error. This would correspond to a signal to noise ratio of roughly 17 dB [2]. Actually, the S/N ratio was in excess of 40 dB, and the corresponding error rate due to thermal noise in the test cascade with this S/N would be vanishingly small.

For actual field installations, the thermal noise from each subscriber house drop will add since the signal paths all converge to the trunk and eventually the Head End and LPC. For an extremely large CATV system, perhaps close to a worse case, let us assume we have approximately 300 miles of strand, and 1,000 reverse amplifiers. The resulting S/N calculated for reverse amplifiers with a noise figure of 10 dB, 23 dB of gain, operating at a +32 dBmV output level is 28 dB for a 4-MHz bandwidth [3]. This will again result in a vanishingly small error rate for data signals but a very poor upstream video signal.

In El Segundo, there will be approximately 160 reverse amplifiers which will cause no thermal noise problems for the SRS but may degrade video picture quality. In this event, provision has been made to operate in a type of hub fashion with two trunk lines in place of one.

Some attempt was made to determine the performance of the system with simulated impulse noise and with interfering carrier signals.

Impulse noise such as might be produced by ignition noise or corona from a high voltage power line was simulated by using 50 nanosecond pulses at repetition rates which were varied from 100 Hz to above 100 KHz. The exact pulse width was varied to place the peak of the resulting noise spectral distribution at the center frequencies of the downstream and upstream SRS carriers, i.e., 110 MHz and 23 MHz, respectively. The levels of the impulses were adjusted for the highest value which did not produce errors. No errors were observed in either downstream or upstream transmissions for a peak SRS carrier level to equivalent 4 MHz bandwidth RMS noise ratio of 14 dB. During the downstream measurements, the noise signals on TV Channels 2 thru 6 were such that the video picture was badly disturbed, while Channels 7 thru 13 were also seriously degraded.

In the case of CW interference such as might be produced by radiation from a broadcast station, the interfering carrier was swept across the SRS downstream and upstream bands and the amplitude varied until errors were detected. The peak SRS signal carrier to CW carrier beyond which errors would occur was measured at 20 dB for downstream reception, while the upstream value was 6 dB. The excellent behavior in the upstream direction is attributed to the hard limiting employed in the upstream PSK receiver, which produces a "capture" effect.

In the above tests, the SRS downstream and upstream carrier levels were approximately the same as the respective TV video carrier levels.

With regard to CW interference and impulse noise, SRS utilizes a high pass filter and a frequency converter between the drop line and the TV set which will effectively block spurious signals picked up at the subscriber's TV set from entering the cable in the upstream direction. Entry of these interfering signals outside the home can be prevented where they occur by effectively shielded drop lines and good workmanship in the installation of the entire cable system.

SINGLE CABLE TESTS

While the El Segundo installation is a two-cable system, it is believed that there also will be many applications where single cable systems will be used for two-way communication. For this reason, SRS is also currently undergoing operational tests using the single cable cascade shown in Figure 9.

This system utilizes a cascade of 16 Theta-Com XR2 two amplifiers and a line extender, with 22 dB spacing measured at 270 MHz between trunk amplifiers.

In addition, to demonstrate the practicability of complete two-way CATV system operations including Local Distribution Service, a Theta-Com two-way AML multichannel microwave link was added to the system. The AML system relays the Head End VHF and LPC SRS downstream signals to the cascade which, in turn, drives the SRS terminal and TV receivers. Return signals from the SRS terminal and a TV camera are fed back upstream thru the cascade to a second AML transmitter. A second AML receiver feeds the upstream SRS and video signals to the Head End and Local Processing Center to complete the two-way loop.

The overall system is shown in the functional block diagram of Figure 10. The entire system performed successfully, and will be demonstrated live at the 1972 NCTA Convention using the actual hardware. It was inconvenient to transport the Local Processing Center for display at the NCTA Convention, and in its place a small fixed program computer was constructed to demonstrate some of the basic services. A computer display panel, shown in Figure 12, was also designed to clearly display the performance of various services.

An interesting and potentially popular and useful service is demonstrated in this equipment. A TV camera at the subscriber terminal relays TV pictures upstream of the home or business location. The camera is actuated by an accessory control command signal which can be furnished by the LPC at any desired time. The upstream video information is converted in frequency at the Head End to a restricted channel (Channel F) and is redirected downstream to an eligible subscriber or subscribers, whose individual eligibility to view the channel is controlled by the LPC. Thus, a video program initiated anywhere in the cable system can be routed to any particular subscriber, group of subscribers, or all subscribers in the CATV system.

Important applications of this service include the following:

a) Home or business protective surveillance and relay of both video and digital alarm signals to the appropriate protective agency or municipal arm.
b) Educational instruction in the home or local schoolroom with relay to the educational center and/or other students.
c) The relay of civic, sporting or news events from any place within the cable system to the home on a fee or free basis.

In addition to single cable two-way systems which can be installed with integral two-way distribution equipment in new construction, there is also the need to retrofit existing one-way systems with two-way capability at minimal cost.

In these cases, the existing downstream amplifiers will be retained and new upstream amplifiers and filters will be retrofitted into the system. The cascade shown in Figure 11 is applicable to the situation. It consists of 32 existing Theta-Com XR downstream amplifiers, retrofitted with 16 Theta-Com XR2SL amplifiers and 32 XR2CF series filters for upstream transmission. The downstream amplifiers are mounted on the front of the racks while the upstream retrofitted components are mounted on the top.

COMPUTER SOFTWARE CONSIDERATIONS AND TESTS

It needs to be emphasized that a successful two-way interactive communication involves not only subscriber terminals, a two-way cable system, and equipment to modulate and demodulate data signals on r.f. carriers - but also a reliable and efficient computer system which is generally associated with the head end. The computer, in turn, requires software control to perform its function of interrogation of the subscribers and more important, servicing the subscriber's needs.

It would be misleading to consider only the time required to interrogate subscribers if we wish to determine the actual time a given two-way system requires to handle the subscriber's requests. The degree of traffic volume and diversity of services which can be accommodated by a given computer software system are also significant factors in evaluating the overall capability of a two-way system.

In these early days of two-way CATV systems, these considerations may be overlooked, or de-emphasized as less important than introducing some form of hardware into public test and use as soon as possible. While the view is to some extent understandable, it may be shortsighted from the cable system operator's vantage in that it may lead to early obsolescence of systems which are limited in the ability to handle large numbers of subscribers and many services or which cannot service heavy traffic demand economically, efficiently, or at all.

Viewed in proper perspective, rapid interrogate and response times, however, are certainly important qualities for any effective system. Two factors determine this portion of the total servicing time required: first, the speed of data transmission and second, the effect of propagation delay of the cable system.

The SRS system transmits digital data downstream and upstream at a rate of 1 megabit per second. The effects of propagation delay are effectively reduced to a negligible amount in the SRS system by the use of proprietary system design features. The combination of the relatively high bit rate and the reduction in the effects of propagation delay permit a total basic interrogation and response time less than approximately 2.4 seconds for 50,000 subscribers.

In systems which do not effectively eliminate the effect of propagation delay, interrogation-response sequences must allow a time delay equal to twice the propagation time between the computer and the farthest subscriber in order to avoid the possibility of interfering responses from 2 subscribers. For a maximum cable distance of 10 miles, the comparable time required to poll 50,000 subscribers would increase to approximately 7.9 seconds, an increase of approximately 325% in elapsed time. Depending on the service being provided, there may be several interactive contacts required between computer and subscriber to complete the required sequence of events which will increase the service time proportionately.

The use of two-way microwave relays between the head end and the cable system will also directly add further propagation delay depending on the length of the microwave path. For an additional 10 miles due to microwave link path length, the time to service 50,000 subscribers would increase from 7.9 seconds to approximately 13.3 seconds, while the SRS service time would remain substantially constant at 2.4 seconds.

Other significant factors in determining actual service time are the speed of the operation of the computer in performing instructions, the core memory cycle time, the access times to disk memory and magnetic tape recorder, when required, and the overall efficiency of the software program controlling the data processing task. The time required for the performance of these operations is generally additive to the basic interrogate-response times discussed previously, since the subscriber responses must be received by the computer before the processing of the responses and service requests can occur. Related to these factors are the economic factors involving tradeoff considerations with respect to the cost of the computer and its peripherals. Increasing the amount of core or semiconductor memory used, for example, may speed up service time but the cost may increase prohibitively.

Depending on the selection of the computer, its peripherals, and the programming efficiency, the actual time to service 10,000 subscribers with a variety of services and heavy traffic volume may increase prohibitively for services in which the interaction time should be short (say, 10 seconds or less) to be attractive to the subscriber.

The SRS computer hardware and software have been selected and designed to permit the economical delivery of services to subscribers under heavy traffic conditions generally within a few seconds. In the Theta-Com laboratories, a computer program was prepared to simulate the simultaneous purchase of any Premium TV channel by 1,000 subscribers. The average time required to provide this service to the 1,000 subscribers was measured at 1.7 seconds. This time included preparing a billing record of each purchase on magnetic tape.

These simulation tests will be continued and extended to include different "mixes" of the various services and variable traffic volumes.

In the field at El Segundo, various tests will be conducted which will proof test the software design and overall system performance under dynamic conditions. When 1,000 terminals have been installed, traffic handling performance can be demonstrated based on real-life requirements. Other tests planned include intercommunication between the SRS Local Processing Center and other data processing and computer systems such as time shared large scale computers, reservation systems, message switching and merchandising systems.

TESTS OF SERVICES

The various services which will be tested by the SRS system can be categorized broadly as follows:

a) New Services: Services which are not widely available to the public at present.

b) Existing Services: Services which are presently available at the home using other means, but which would provide some improvement to the public or other user such as personal convenience, cost savings, greater flexibility, time savings, etc.

Under "New Services," we may list Premium Television, Restricted Channels, Frame Grabbing, Channel Polling, Opinion Polling, Interactive Education in the Home, Audience Participation, Off-track Betting (where legalized).

Under "Existing Services," we may list Meter Reading, Shop-at-Home, Reservation Services, Emergency Services, and various derivatives of these services.

The "New Services," by definition, will provide new experiences for the public which may well be attractive enough by themselves to gain widespread acceptance of interactive CATV.

Conversely, the improvements which may be offered by some of the "Existing Services," such as Shop-at-Home may furnish the initial trigger for widespread utilization of interactive services.

Once significant acceptance is obtained for some of the services, the cost of home terminals can be substantially justified on the basis of the additional revenues provided. At this point, some of the services listed as "Existing Services" may well be diverted from their present media to CATV. This could occur on the basis of the added improvements referred to above, the formation of new public habit patterns, and increasing availability of CATV and interactive systems in competition with other established media.

In El Segundo, it is planned to test the aforementioned services and others, where practical. The initial tests utilizing some 30 Subscriber Terminals will be developmental tests to demonstrate and develop the services for cable system operators and other enterpreneurs in a realistic environment, i.e., on an operating two-way cable system in subscribers' homes. The tests will take place over, perhaps, six months and phase into testing 1,000 terminals as they are installed in subscribers' homes.

The tests utilizing 1,000 terminals will deliver actual services to the subscribers on a fee basis, where applicable. The reaction of the subscribers to these services, the profitability of the services, and the need for change or modification in the implementation of the services will be studied in this phase.

CONCLUSION

The El Segundo tests are planned to comprehensively demonstrate the technical feasibility of two-way interactive CATV communications, and to attempt to determine public acceptance of the services offered.

With regard to technical feasibility, the results to date have corroborated and considerably extended previous test evidence obtained in the field at Los Gatos, California in 1971, indicating basic soundness of the SRS system design.

With regard to public acceptance, the El Segundo tests will constitute a serious and significant attempt to interact with the life style of the public to determine the roles best suited to this new technological medium and to demonstrate and measure its public value and marketability.

REFERENCES

[1] R. T. Callais and E. W. Durfee, "The Subscriber Response System," paper presented at the 1971 NCTA Convention.

[2] E. D. Sunde, "Ideal Binary Pulse Transmission by AM and FM," The Bell System Technical Journal, November, 1959, pg. 1408.

[3] System Applications brochure for XR2 Equipment, published by Kaiser CATV Division (now Theta-Com CATV Division), Phoenix, Arizona, pg. 43.

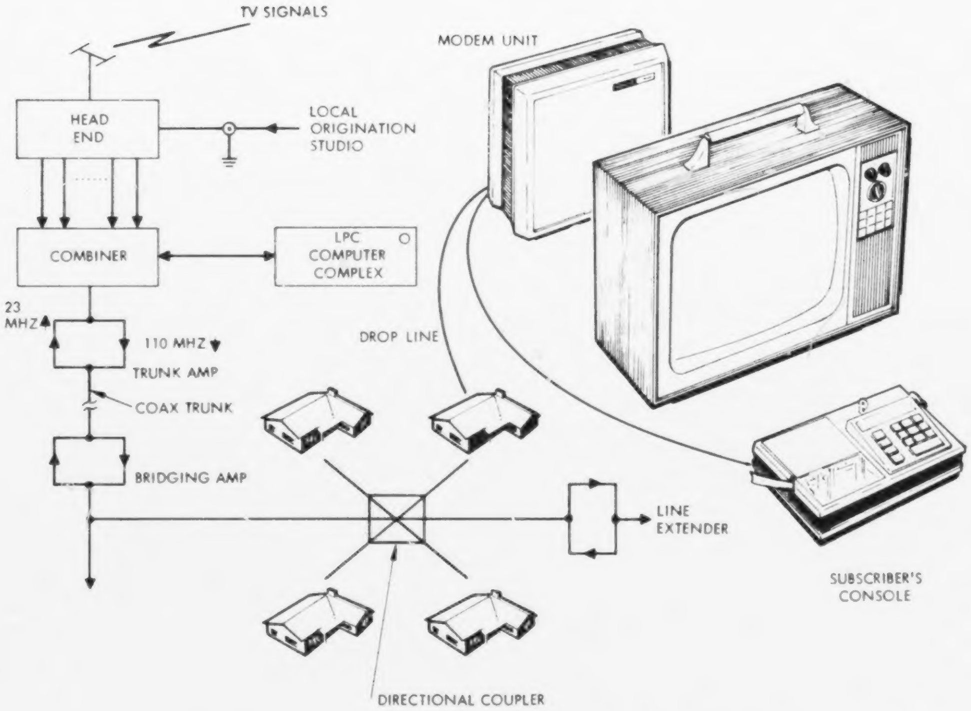

TV SIGNALS
MODEM UNIT
HEAD END
LOCAL ORIGINATION STUDIO
COMBINER
LPC COMPUTER COMPLEX
23 MHZ
110 MHZ
TRUNK AMP
DROP LINE
COAX TRUNK
BRIDGING AMP
LINE EXTENDER
SUBSCRIBER'S CONSOLE
DIRECTIONAL COUPLER

Figure 1 - SRS Basic System Operation

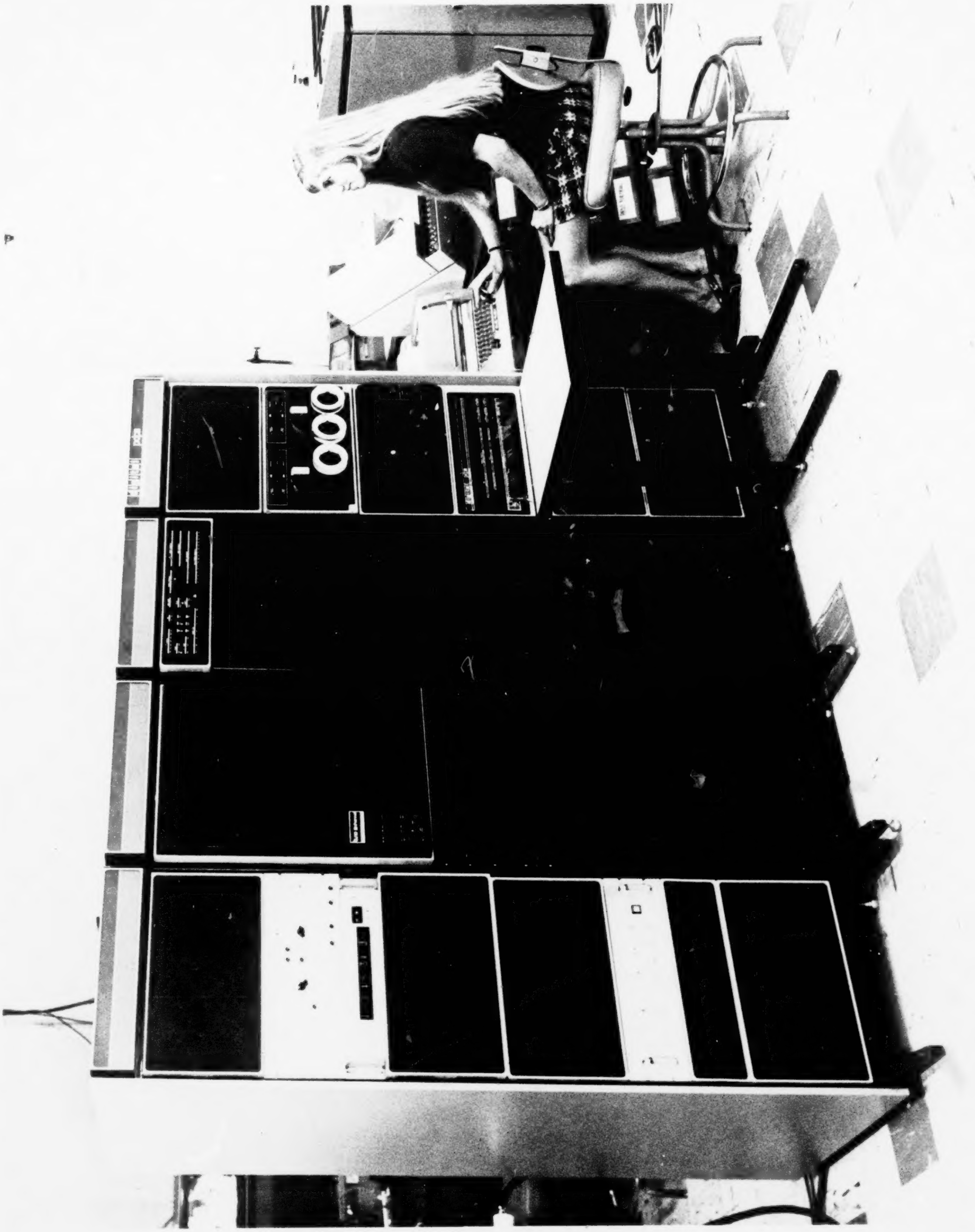


Figure 2 - SRS Local Processing Center

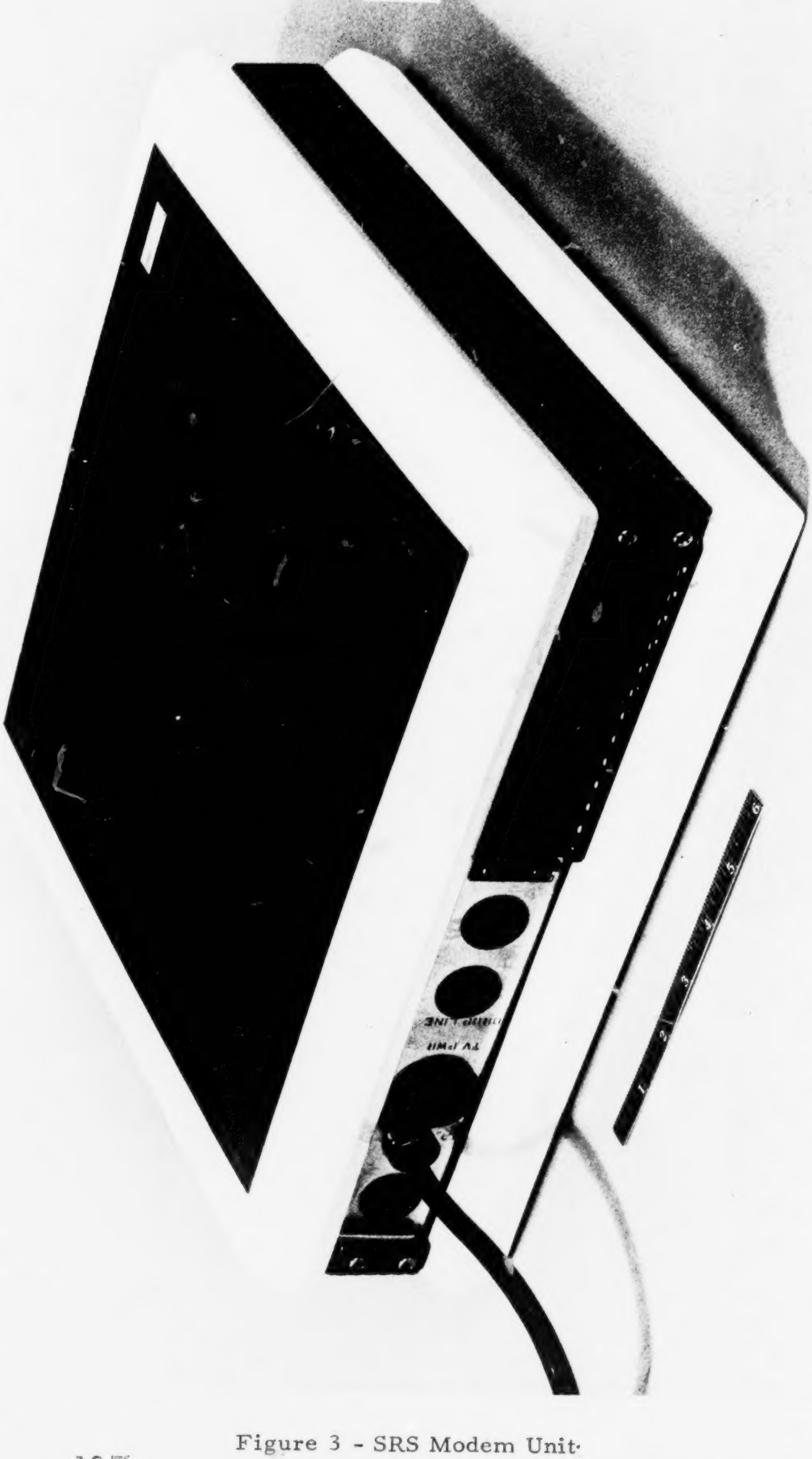


Figure 3 - SRS Modem Unit

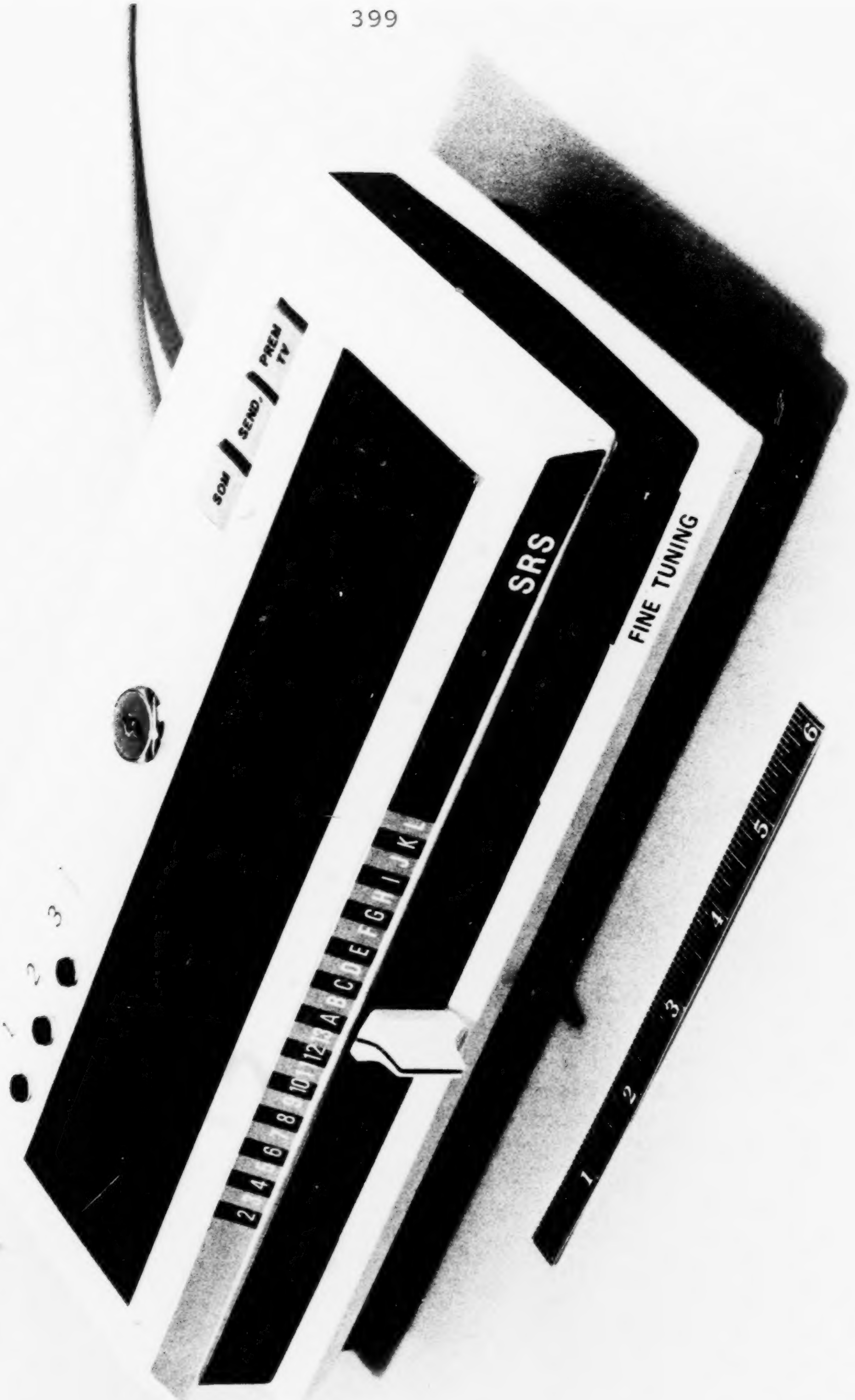

SOM
SEND
PREM TV
SRS
FINE TUNING
2 4 6 8 10 12 A B C D E F G H I J K L
1 2 3
1 2 3 4 5 6

Figure 4 - SRS Model 101 Console

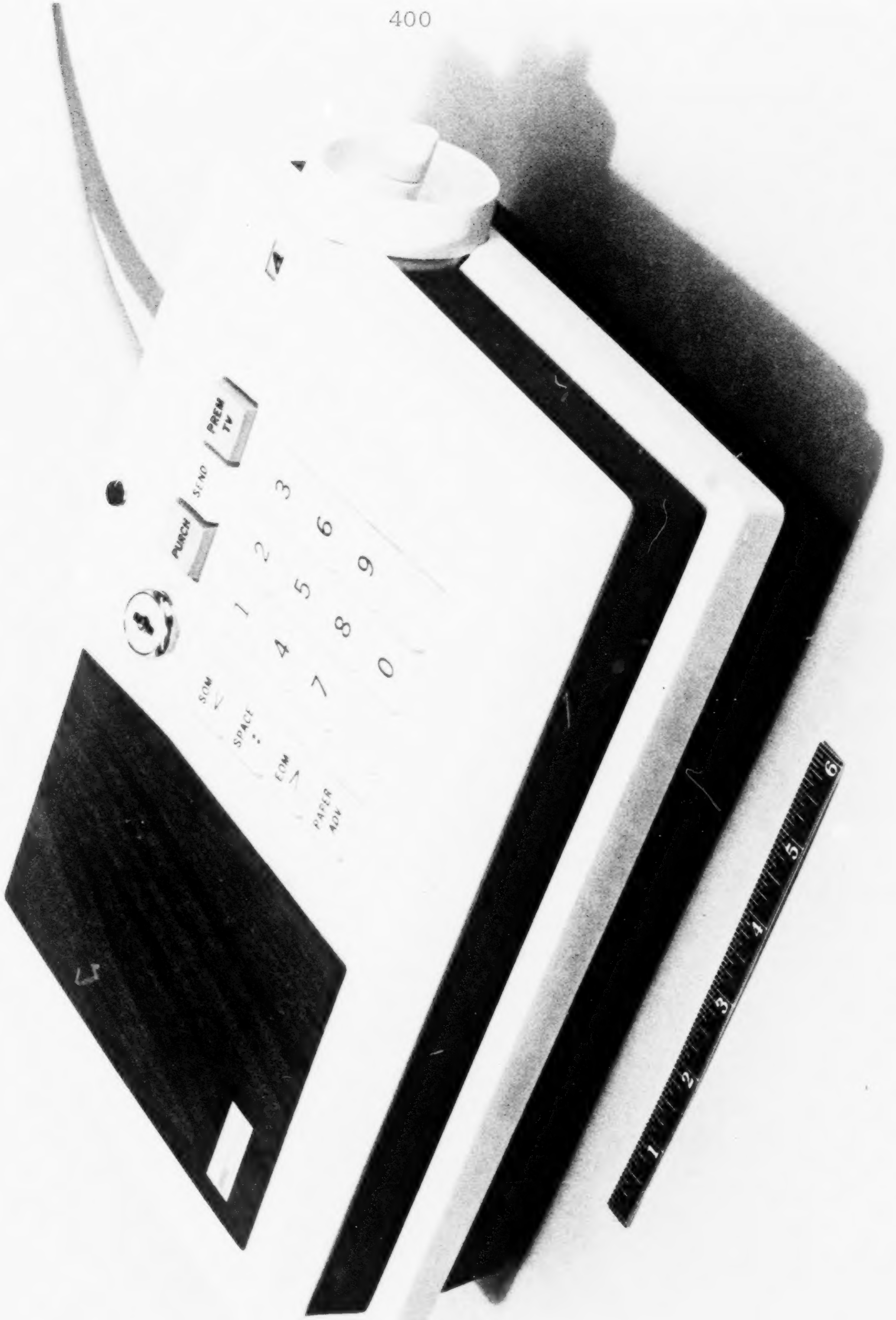

PUNCH
SEND
PREM TV
1
2
3
4
5
6
7
8
9
0
SOM
SPACE
EOM
PAPER ADV
1
2
3
4
5
6

Figure 5 - SRS Model 102 Console

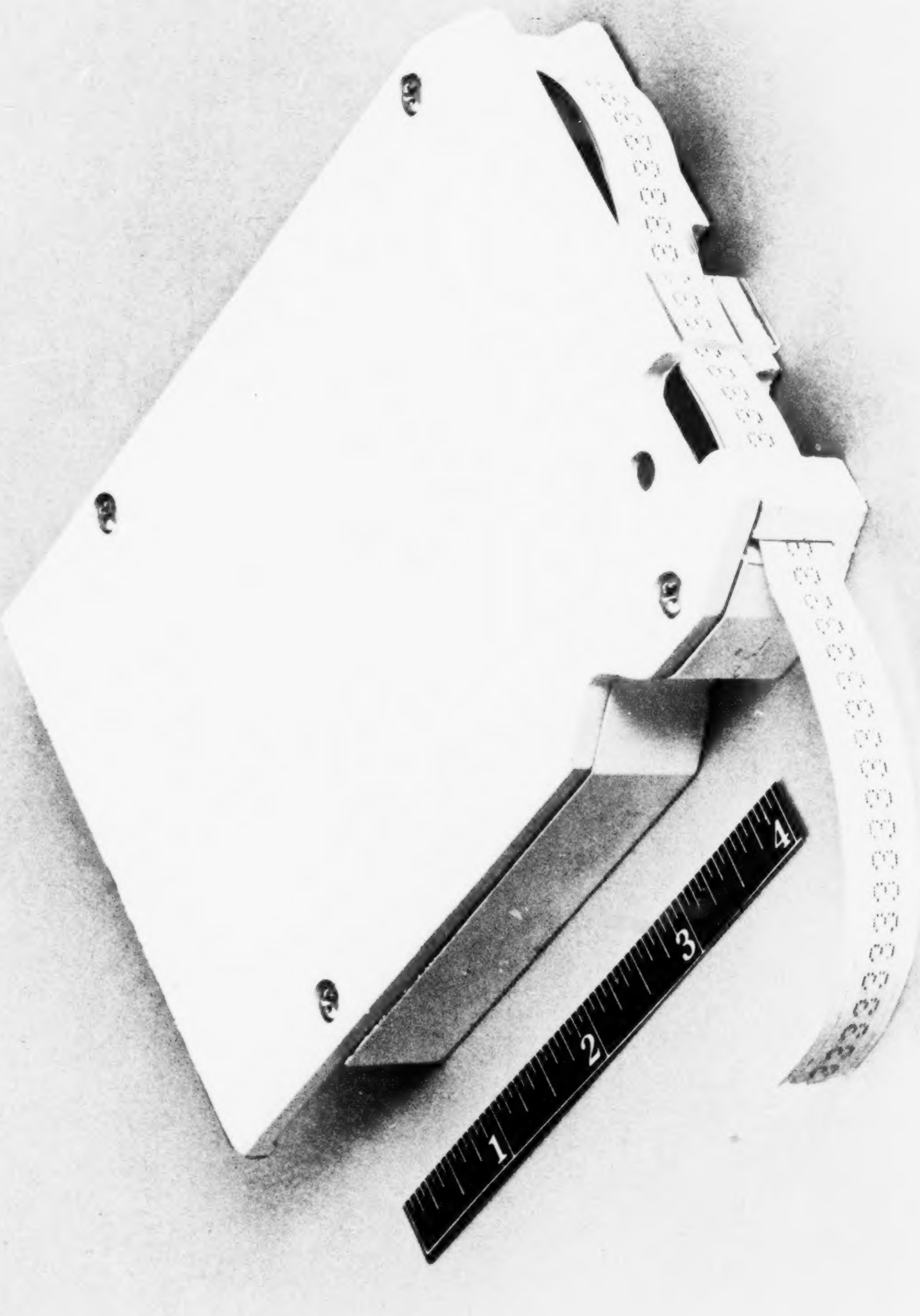


Figure 6 - SRS Paper Tape Cartridge

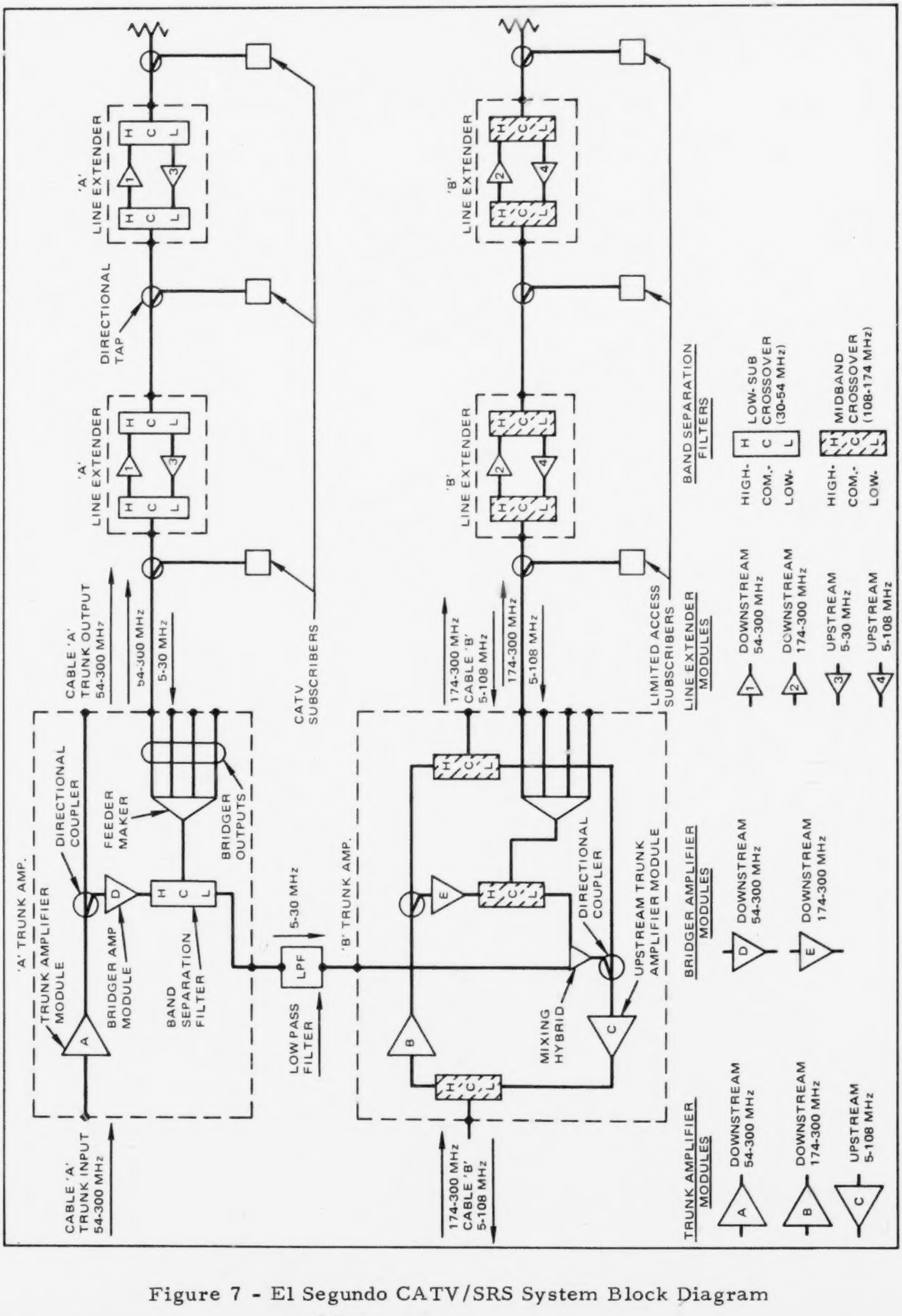

'A' TRUNK AMP.
TRUNK AMPLIFIER MODULE
DIRECTIONAL COUPLER
FEEDER MAKER
BRIDGER OUTPUTS
BRIDGER AMP MODULE
BAND SEPARATION FILTER
A
D
H C L
CABLE 'A' TRUNK INPUT 54-300 MHz
CABLE 'A' TRUNK OUTPUT 54-300 MHz
54-300 MHz
5-30 MHz
DIRECTIONAL TAP
'A' LINE EXTENDER
1
3
CATV SUBSCRIBERS
LOW PASS FILTER
LPF
5-30 MHz
'B' TRUNK AMP.
B
C
E
MIXING HYBRID
DIRECTIONAL COUPLER
UPSTREAM TRUNK AMPLIFIER MODULE
174-300 MHz CABLE 'B' 5-108 MHz
174-300 MHz
5-108 MHz
'B' LINE EXTENDER
2
4
LIMITED ACCESS SUBSCRIBERS
TRUNK AMPLIFIER MODULES
A DOWNSTREAM 54-300 MHz
B DOWNSTREAM 174-300 MHz
C UPSTREAM 5-108 MHz
BRIDGER AMPLIFIER MODULES
D DOWNSTREAM 54-300 MHz
E DOWNSTREAM 174-300 MHz
LINE EXTENDER MODULES
1 DOWNSTREAM 54-300 MHz
2 DOWNSTREAM 174-300 MHz
3 UPSTREAM 5-30 MHz
4 UPSTREAM 5-108 MHz
BAND SEPARATION FILTERS
HIGH- COM.- LOW-
H C L
LOW-SUB CROSSOVER (30-54 MHz)
MIDBAND CROSSOVER (108-174 MHz)

Figure 7 - El Segundo CATV/SRS System Block Diagram

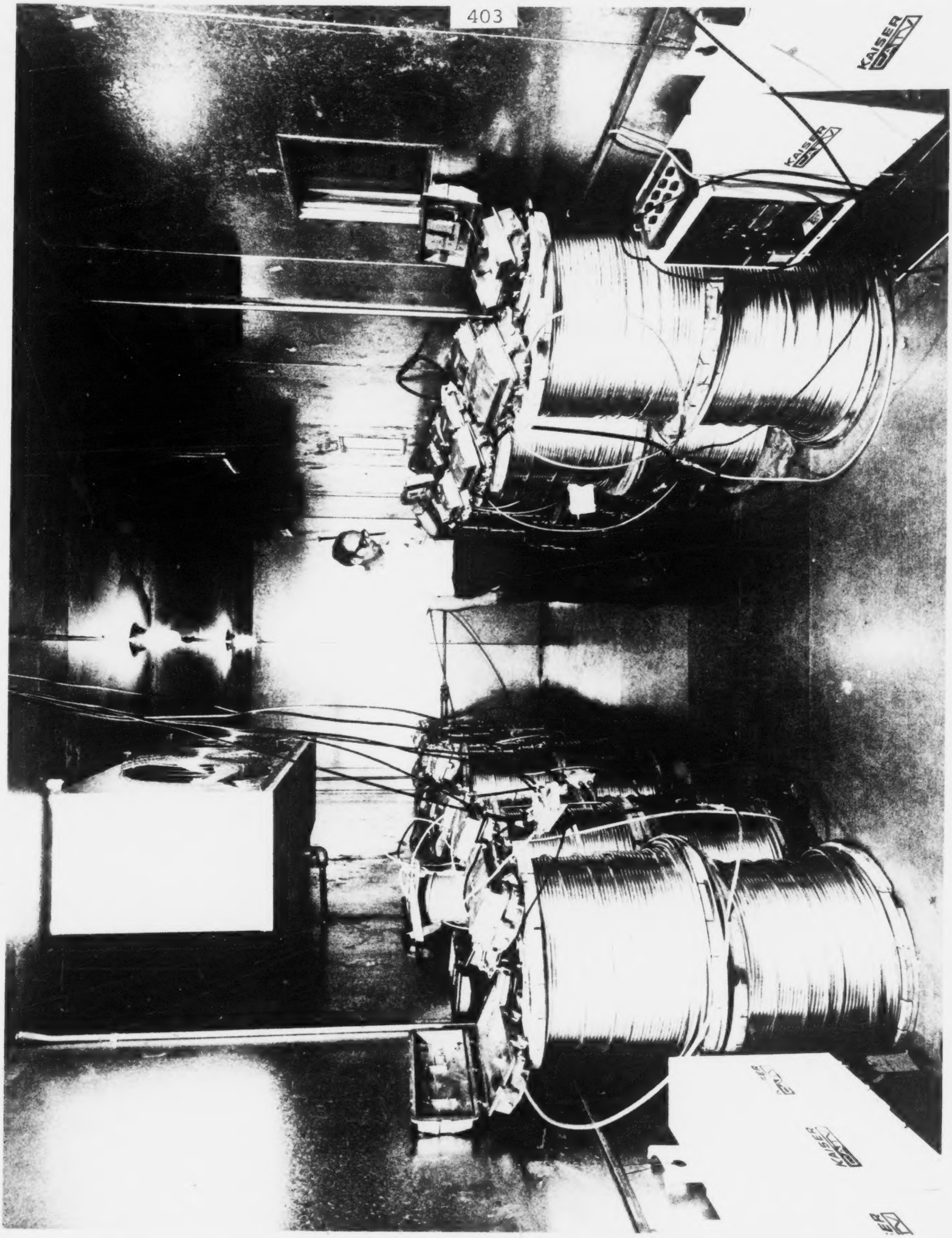

KAISER
KAISER
KAISER
KAISER

Figure 8 - Two Cable Two-Way Cascade

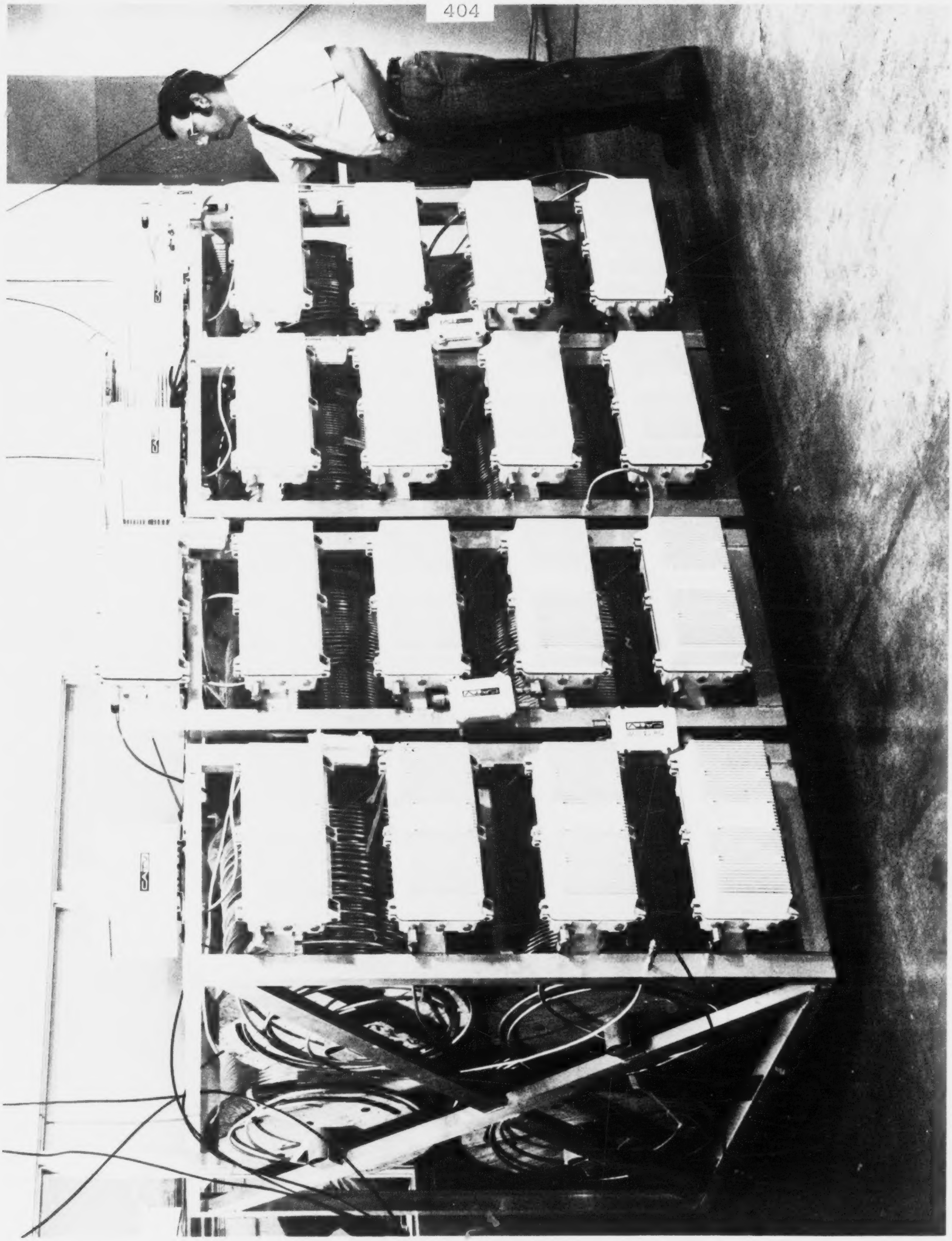


Figure 9 - Single Cable Two-Way Cascade

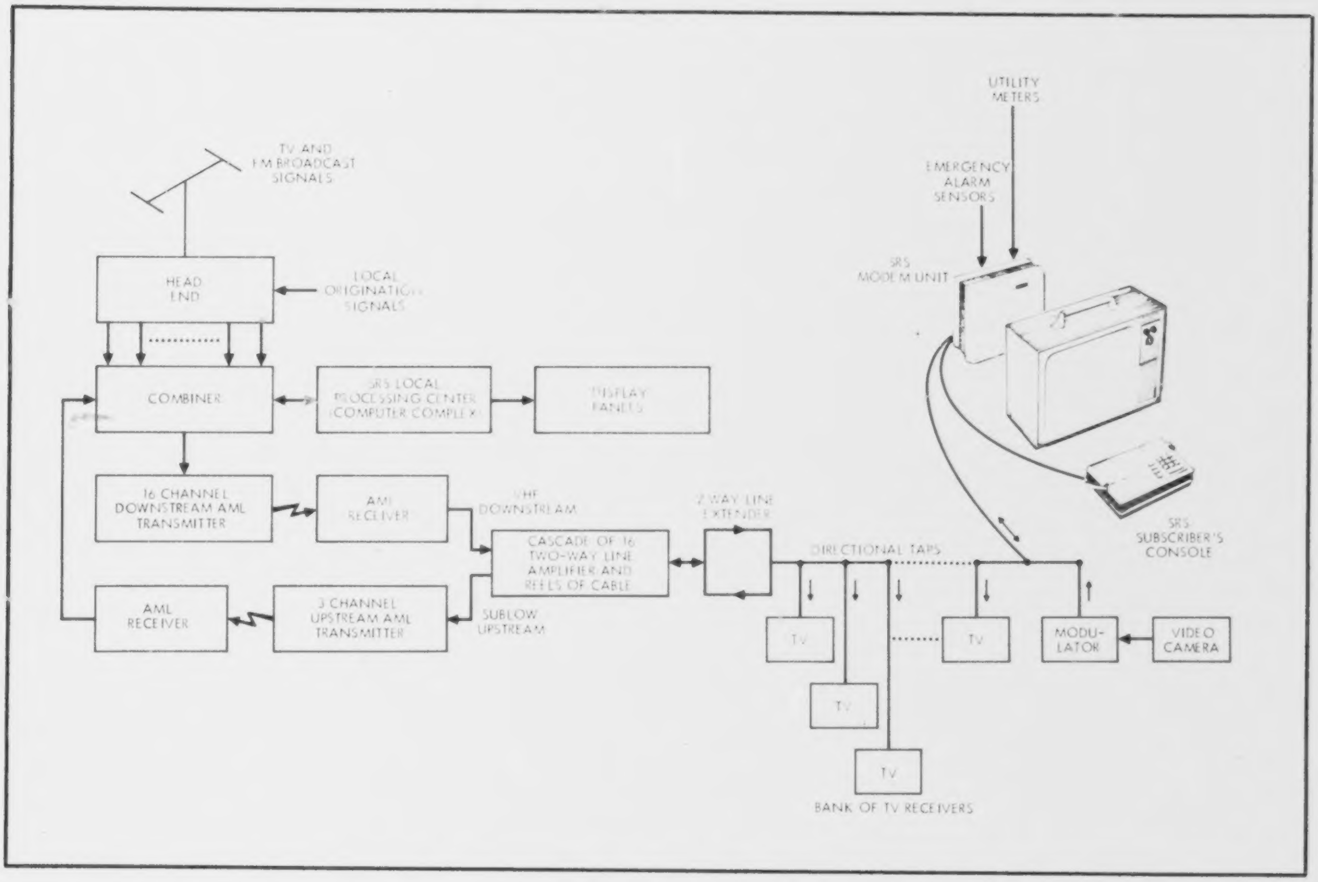

TV AND
FM BROADCAST
SIGNALS
HEAD
END
LOCAL
ORIGINATION
SIGNALS
COMBINER
SRS LOCAL
PROCESSING CENTER
(COMPUTER COMPLEX)
DISPLAY
PANELS
16 CHANNEL
DOWNSTREAM AML
TRANSMITTER
AML
RECEIVER
VHF
DOWNSTREAM
CASCADE OF 16
TWO-WAY LINE
AMPLIFIER AND
REELS OF CABLE
AML
RECEIVER
3 CHANNEL
UPSTREAM AML
TRANSMITTER
SUBLOW
UPSTREAM
2 WAY LINE
EXTENDER
DIRECTIONAL TAPS
UTILITY
METERS
EMERGENCY
ALARM
SENSORS
SRS
MODEM UNIT
SRS
SUBSCRIBER'S
CONSOLE
TV
TV
TV
TV
MODU-
LATOR
VIDEO
CAMERA
BANK OF TV RECEIVERS

Figure 10 - Combined SRS-LDS Operation

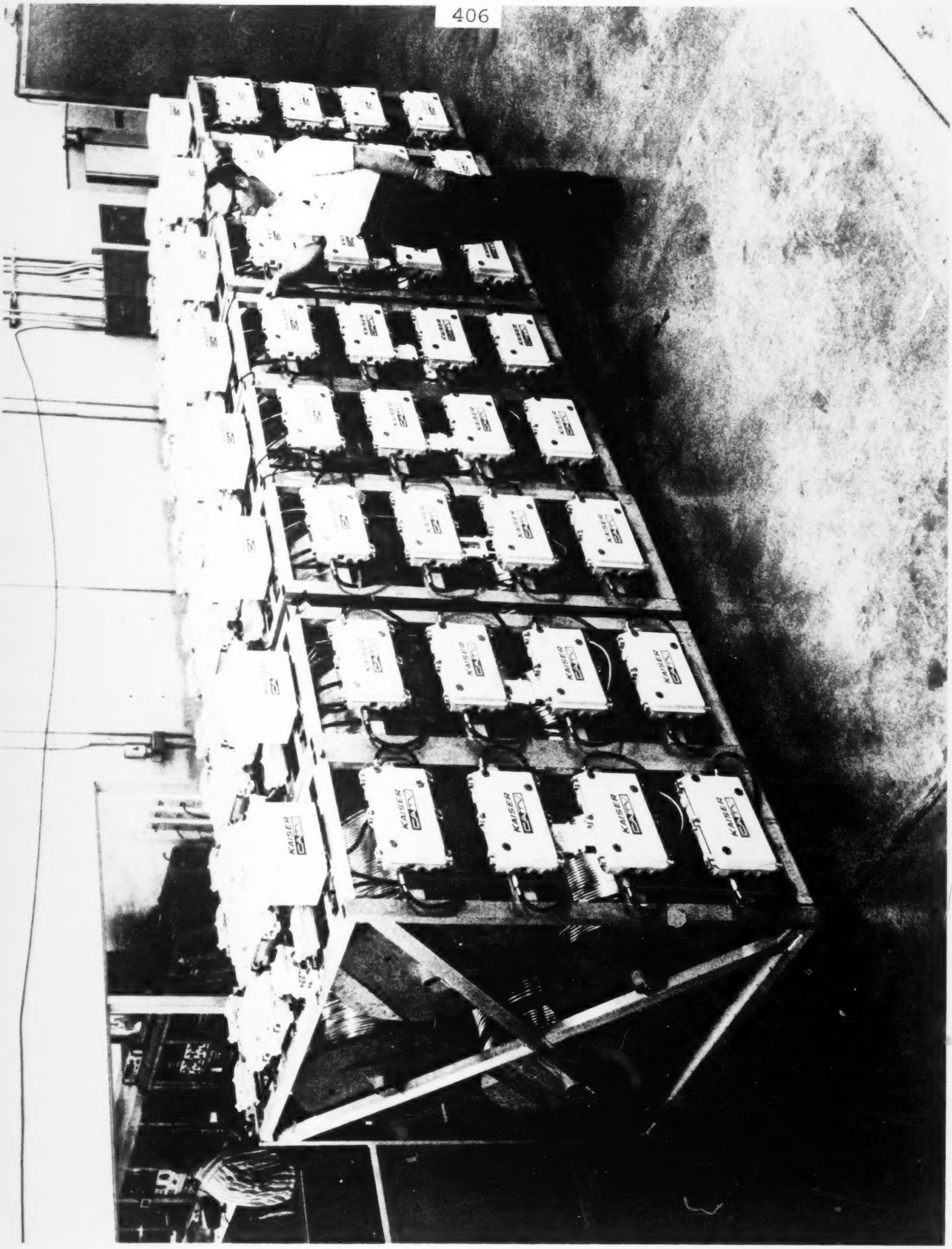


Figure 11 - Single Cable Retrofit Two-Way Cascade

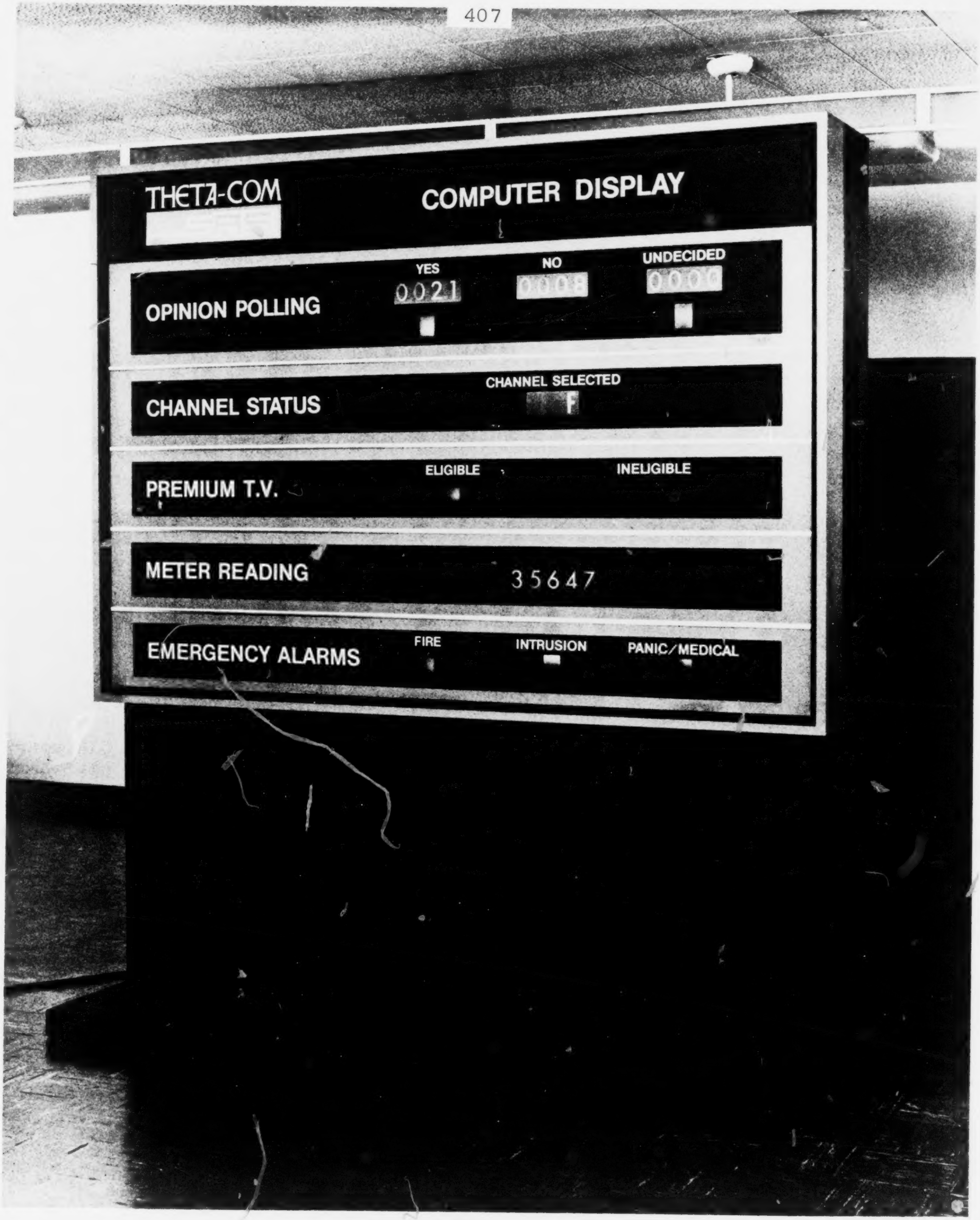

THETA-COM
COMPUTER DISPLAY
OPINION POLLING
YES
0021
NO
0008
UNDECIDED
0000
CHANNEL STATUS
CHANNEL SELECTED
F
PREMIUM T.V.
ELIGIBLE
INELIGIBLE
METER READING
35647
EMERGENCY ALARMS
FIRE
INTRUSION
PANIC/MEDICAL

Figure 12 - SRS Computer Display

HIGHLIGHTS
TECHNICAL SESSION

ADVANCED TECHNIQUES AND DESIGN

Chairman

Michael F. Jeffers
Jerrold Electronics Corp.
Hatboro, Pennsylvania

Speakers

Jack W. Blanchard
Ameco, Inc.
Phoenix, Arizona

Ivan Frisch
Network Analysis Corp.
Glen Cove, New York

Henry Marron
Jerrold Electronics Corp.
Hatboro, Pennsylvania

Gaylord Rogeness
Anaconda Electronics
Anaheim, California

R. Richard Bell
Electronics Group of TRW Inc.
Lawndale, California

Reporter

Frank Haney
Tele-Vue Systems Div. of Viacom
San Rafael, California

1. "Flexicade - An Evolutionary Cable System" - Jack W. Blanchard

Mr. Blanchard pointed out two problems encountered with conventional CATV systems encountered with conventional CATV systems: a) Deterioration over long cable distances and b) Influence of local high ambient RF fields. He showed that a sub-band approach transports from four to seven TV channels in the range of six to forty-eight MHz. Next, a block convention scheme to get the sub-band channels up to standard TV channel frequencies was described. Individual channel amplifier performance characteristics and those of a 32 amplifier cascade were presented.

Another approach described requires special TV tuners for non on-channel signal carriage.

2. "Reliability Through Total Automation of CATV System Design" - Ivan Frisch

Dr. Frisch outlined two advantages of the design by computer approach; i.e., reliability and flexibility. He then showed typical errors introduced by manual designs.

Finally, a computer-operated drafting machine for the drawing out of the computer designed system was described. It was pointed out that a 100 mile plant could be drawn by this computer-drafting machine combination in approximately four hours.

3. "Return System AGC In Two-Way CATV Systems" - Henry Marron

Mr. Marron pointed out the shortcomings encountered by the injection of pilot carriers (in the return direction) - individual pilot carriers may tend to build up (or cancel) depending on their frequency difference and/or temperature variations.

An approach using limited bandwidth white noise pilots with each having control of only a portion of the AGC range of the return amplifiers was described. This approach aberages the return levels of both the pilots and the return signals, thereby not penalizing one for the other.

4. "Contributing Sources and Magnitudes of Envelope Delay in Cable Transmission System Components" - Gaylord Rogeness

Mr. Rogeness listed the many causes of group delay in a CATV system. The major contribution was pointed out to be caused by the crossover filters present in each two way amplifier location.

Several schemes for correction were presented; e.g., including pre-equalization at head-end, use of converters to cause a sub-band channel experiencing one form of group delay distortion to experience a reverse distortion after conversion to a standard TV channel frequency (Ch-2 or Ch-3).

Question: Why is not the delay caused by the crossover filters not corrected by phase correctors at each filter?

Answer: This has not yet been fully investigated.

Question: What is the maximum tolerable chroma to video delay?

Answer: Approximately 178 Nsec.

5. "Elimination of Cross-Modulation in CATV Amplifiers" -
R. Richard Bell

Mr. Bell pointed up the changes in channel capacities and amplifier output levels which have occured since 1964--from 9 channels at 46 dbmv to 35 channels at 50 dbmv.

He discussed some results of his investigations into transistor and circuit limitations. Some of these were:

a) Use of low beta transistors

b) Reduce circuit capacitance so as to flatten out elliptical load line in super band.

c) Junction temperature changes with channel loading.

Question: Have you looked into the use of field effect transistors?

Answer: Their gain per stage was too low to be practical.

FLEXICADE - AN EVOLUTIONARY CABLE SYSTEM

BY J.W. BLANCHARD
Engineering Manager for AMECO, INC.

INTRODUCTION

When the total telecommunications requirements of a cable system for the top 100 markets is considered, it becomes evident that the conventional frequency division multiplexed cable system lacks certain important features that will be needed for the metropolitan areas.

Two of the more obvious shortcomings are:

- 1. It cannot transport high quality television signals over the distances encountered in the metropolitan areas.

- 2. It does not work well in the high ambient signal levels found in most large cities.

To overcome these shortcomings, Ameco is introducing a system concept called FLEXICADE.

The name FLEXICADE has been coined by Ameco to describe a total concept in signal handling and distribution equipment that was designed specifically to provide a cable system capable of meeting the multifaceted industrial and community requirements that exist in these metropolitan markets today. At the same time, however, FLEXICADE offers alternate capabilities that can help the small system owner who needs an economincal system to handle long signal transportation runs through sparsely populated areas.

A partial list of the salient features of FLEXICADE include:

- TV pictures can be made available to the customer without influence of local high ambient signal levels.

- Two way capability is provided without group delay distortion.

- Reverse channel capacity is not limited by the system.

- Forward and Reverse trunk capability may be interchanged to meet changing requirements.

- Low frequency trunk system holds signal degradation to a minimum by minimizing the amplifier cascade.
- Systems are available with 12, 20, 24, 26, 32, 40 channels as standard equipment.

The FLEXICADE concept, in spite of the impressive features, does not represent a revolutionary concept in cable television. Instead it is a concept that has evolved from Ameco's DISCADE[1]/ system design experience. The hardware that has been designed to implement the concept is new, and designed with the latest components, but the principles are merely an extrapolation of existing techniques that have been proven through years of experience. Hence, it can be said that FLEXICADE is an evolutionary system.

II. GENERAL SYSTEM DESCRIPTION

The FLEXICADE system combines the virtues of space division and frequency division multiplexing along with sub-band signal transportation to provide a variety of possible system configurations to meet many different requirements. To understand the various system configurations available, let us first examine the basic constituent elements that are used to make up the systems.

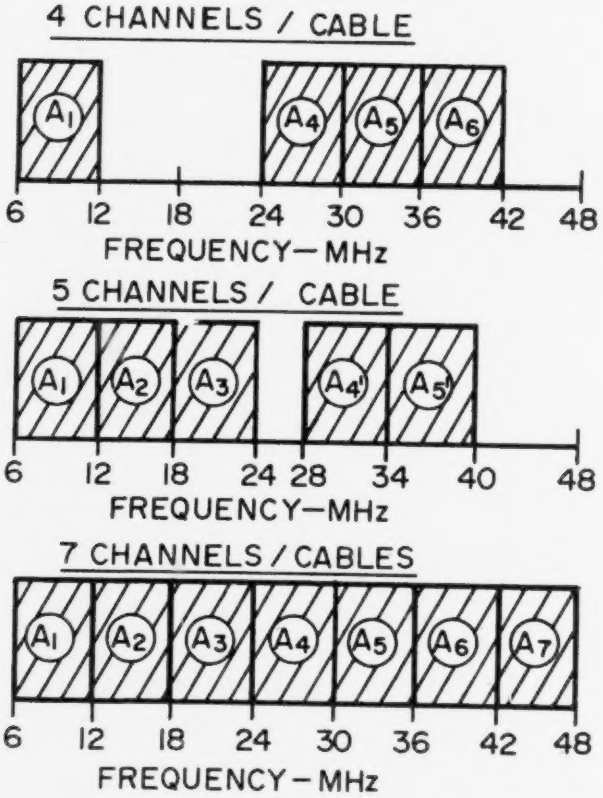
TRANSPORTATION SYSTEM

The FLEXICADE transportation system uses the frequency spectrum between 6 and 48 MHz for sub-band signal transmission on conventional coaxial cable. The picture and sound carrier assignments for each of the channels A1 through A7, listed in Figure 1, are uniformly spaced at 6 MHz. This allows a maximum of 7 television channels to be handled in the 42 MHz bandwidth available.

There are two versions of the transportation system available, a 4 channel per cable system that uses Channels A1, A4 and A5 and A6, and a 7 channel per cable system that uses the entire bandwidth of the transportation system to handle channels A1 thru A7.

When the FM radio band is being transported it occupies the 20 MHz band between 15 and 35 MHz on the cable.

The amplifiers that were designed for this application are Ameco's new SUBNOVA line of R.F. amplifiers. These are high quality trunk line amplifiers that use the latest hybrid push-pull circuits to provide the signal amplification. A dual pilot carrier AGC system is used to provide absolute control of output level and slope over a temperature range of -40 to +140 degrees Fahrenheit. The basic amplifiers are designed to provide 30 dB of flat gain over the frequency range of 2-110 MHz in this application. Plug-in equalizers provide gain equalization for the coax cable over the frequency range from 6 MHz to the upper picture carrier at 37.25 MHz or 43.25 MHz depending on the number of channels carried on the cable.


4 CHANNELS / CABLE
A1
A4
A5
A6
6 12 18 24 30 36 42 48
FREQUENCY—MHz
5 CHANNELS / CABLE
A1
A2
A3
A4'
A5'
6 12 18 24 28 34 40 48
FREQUENCY—MHz
7 CHANNELS / CABLES
A1
A2
A3
A4
A5
A6
A7
6 12 18 24 30 36 42 48
FREQUENCY - MHz

CHANNEL	BAND—MHz	CARRIER FREQUENCY-MHz	
		VISUAL	AURAL
A_1	6-12	7.25	11.75
A_2	12-18	13.25	17.75
A_3	18-24	19.25	23.75
A_4	24-30	25.25	29.75
$A_{4'}$	28-34	29.25	33.75
A_5	30-36	31.25	35.75
$A_{5'}$	34-40	35.25	39.75
A_6	36-42	37.25	41.75
A_7	42-48	43.25	47.75

FIGURE 1- TRANSPORTATION SYSTEM-SPECTRUM UTILIZATION

Figure 2 graphically translates the loss of a cascade of 32 Sub Nova amplifiers into distance for three of the standard size coax and clearly illustrates the advantages of using low frequency for the FLEXICADE transportation system.

Here, a four channel per cable system with the upper picture carrier at 37.25 MHz, requires only 32 amplifiers for a 47 mile transportation run. In other words the amplifiers are spaced 7880 feet apart or nearly 1.5 miles when using .750 inch cable. By comparison the conventional trunk amplifier, with 22 dB of gain at 300 MHz is spaced 2000 feet using the same size cable. The Sub Nova transportation system will therefore use less amplifiers by the ratio of 3.94 to one over the conventional system for the same length of transportation run. The advantages that this offers should be obvious. Further, at the end of the 32 amplifier cascade the operating performance characteristics of a 4-channel system at 68°. would be:

Signal - to - noise ratio	≥	45 dB
Cross Modulation distortion ratio	≤	-60 dB
2nd Order Beat products	≤	-61 dB

Figure 3 tabulates the operating performance characteristics of an individual AGC'd amplifier over the worst case cable temperature extremes of -40 to +140° Fahrenheit. These data take into account the action of the amplifiers as the AGC acts to correct for the changes in cable attenuation with temperature. From these tabulated characteristics it can be noted that while the output Cross Modulation distortion changes very little with temperature, the Noise Figure changes by a relatively large amount going from 6.9 dB at +140°F to 9.6 db at -40°F. Contrary to first reactions this is not a bad situation since this occurs at the same time that the input signal level has increased from 7.3 dBmV to 12.8 dBmV. The net result is that at this "worst case" Noise Figure of 9.6 dB the output signal to noise ratio, the parameter of real concern, only degraded by 0.4 dB below the value at 68°F. This trend prevails in all cases with the result that the change in input signal to noise ratio caused by cable changes with temperature tends to be offset by the amplifier Noise Figure changes, thereby holding the output signal to noise ratio relatively constant.

In general the Sub Nova amplifier has been carefully designed to optimize its performance characteristics within the framework provided by the state of the art components. This means that long amplifier cascades can be used with minimum effect on the signals being carried.

Each Sub Nova amplifier is symmetrically packaged so the direction of amplification can be reversed by physically plugging the amplifier into its housing in a reversed sense. Thus forward and reverse lines may be readily interchanged as the system needs change. Detailed electrical and mechanical specifications are tabulated in Appendix "A".

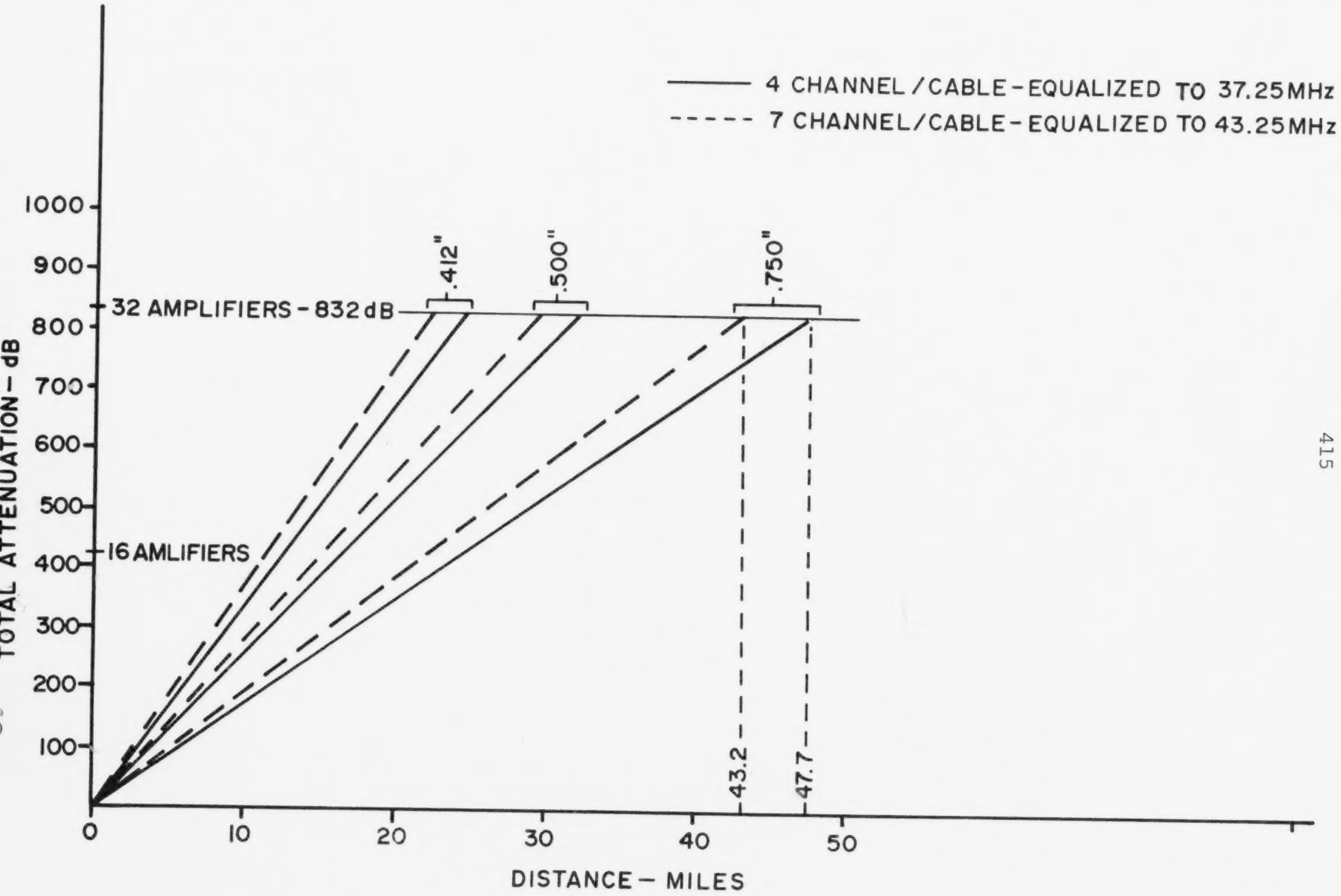

4 CHANNEL / CABLE - EQUALIZED TO 37.25MHz
7 CHANNEL/CABLE - EQUALIZED TO 43.25MHz
TOTAL ATTENUATION - dB
1000
900
800
700
600
500
400
300
200
100
32 AMPLIFIERS - 832 dB
16 AMLIFIERS
.412"
.500"
.750"
43.2
47.7
0
10
20
30
40
50
DISTANCE - MILES

FIGURE 2- CASCADE DIAGRAM-SUB NOVA AMPLIFIER

TEMPERATURE °F	2/ INPUT SIGNAL dBmV @ Frequency		2/ INPUT S/N RATIO dB @ Frequency		3/ OPERATING NOISE FIGURE dB @ Frequency		OUTPUT S/N RATIO dB @ Frequency		4/ OPERATING CROSS MOD- dB
	f1	f2	f1	f2	f1	f2	f1	f2	
-40	12.8	12.9	71.8	71.9	9.6	8.5	62.2	63.4	$\boxed{90\ 5/}$
+68	11.6	9.5	70.6	68.5	8:0	7.3	62.6	61.2	92
+140°	10.8	7.3	69.8	66.3	7.3	$\boxed{6.9\ 5/}$	62.5	59.4	92

f1 = 7.25 MHz , f2 = 43.25 MHz

NOTES:

1/ All characteristics are with the amplifier spaced 26 dB of cable

2/ After equalizer

3/ With equalizer in place

4/ 4 channel, 5 dB Block Tilt - output level = +36 dBmV, input = 10 dBmV @ 68° F

5/ Amplifier Specifications (See Appendix A)
NOISE FIGURE - 7.5 dB @ Min. full gain, f= 43.25 MHz W/O Equalizer

FREQUENCY TRANSLATION EQUIPMENT

Since the signals in a FLEXICADE system are transported at sub-band (6-48 MHz), frequency translation equipment is required at both the Head End and at some other point in the system to make the frequency transition from the standard VHF channels to sub-band and back again.

HEAD END

At the Head End frequency translation is accomplished by a heterodyne signal processor with the output directly on the sub-band channel desired. The signal processor that is used is Ameco's new MARK II CHANNELEER.

This new MARK II CHANNELEER features:

An FET front end for better S/N ratio and over load capability

Improved filtering for better adjacent channel selectivity

Improved temperature stability

These improved features assure that the signal to noise ratio will be a minimum of 59 dB, as long as the input signal is above +6 dBmV, and that all other undesired signals will be at least 60 dB below the desired signal level under normal operating conditions.

UNIVERTOR

Four models of strand mounted Hub Converters called Univertors are available to convert the sub-band spectrum back to VHF at the end of the transportation run. The choice of which Univertor to use depends entirely upon the services that will be provided to the customer and the choice of set-top converter, if any, that will be used.

MODEL I UNIVERTOR

The frequency translation scheme of the Model I Univertor is depicted in Figure 4. This particular conversion scheme is also compatible with the TYPE II FLEXICADE system to be explained later. Three input cables with four television channels per cable plus one cable with FM radio are provided at the input to this converter. Conversion is accomplished with six converters. Three single channel converters accept the 6-12 MHz band at the input and provide an output on Channels 5, 6 and 13. Three block converters accept an input of 24-42 MHz and provide at the output Channels 2, 3 & 4, Channels 7, 8 and 9 and Channels 10, 11 and 12.

The FM radio band is carried on the trunk between 15 and 35 MHz and is block converted from this spectrum back to the standard 88 to 108 MHz FM radio band. After conversion the FM is multiplexed onto the output cable along with the twelve television channels.

The output amplifier of the converter is a push-pull hybrid amplifier that drives two output ports at a nominal output level of +36 dBmV or one output port to a level of +40 dBmV.

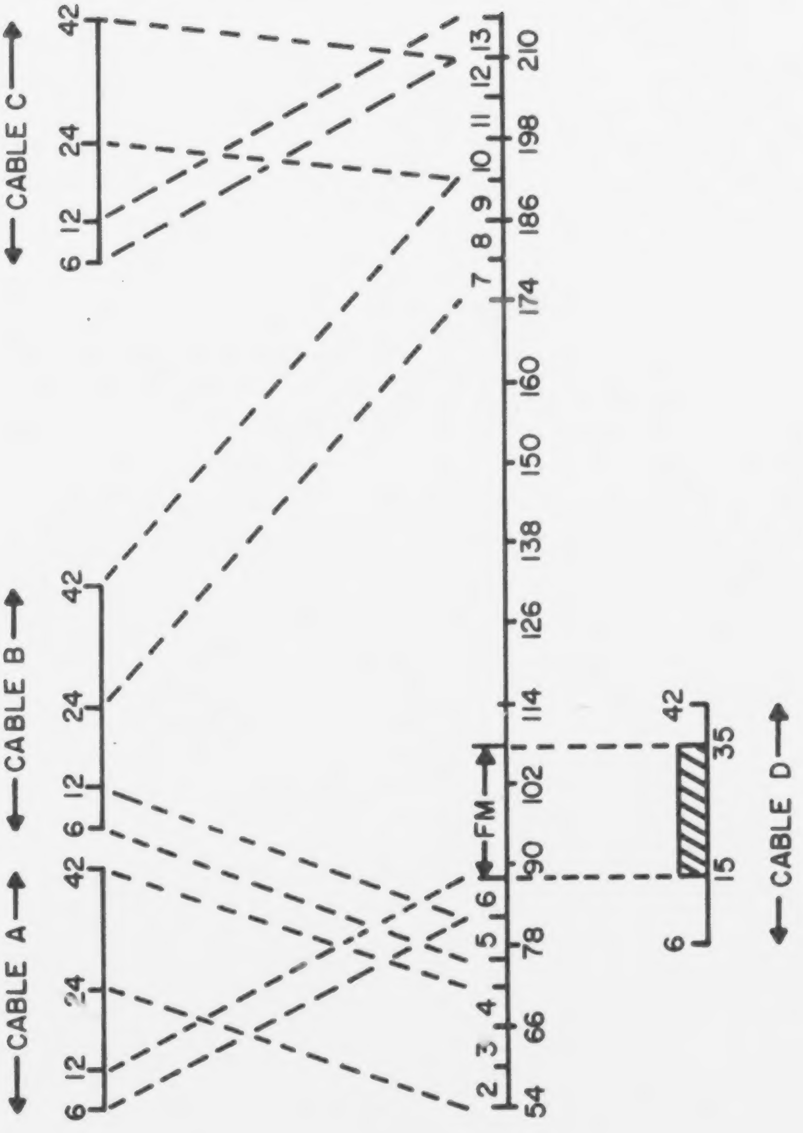

CABLE A
6
12
24
42
CABLE B
6
12
24
42
CABLE C
6
12
24
42
2
3
4
5
6
FM
7
8
9
10
11
12
13
54
66
78
90
102
114
126
138
150
160
174
186
198
210
CABLE D
6
15
35
42

FIGURE 4- FREQUENCY TRANSLATION - UNIVERTOR, MODEL I

In this manner the output is high enough so it can drive a feeder line directly. This drive level may be reduced from +40 dBmV to +32 dBmV to make the output level suitable to drive a trunk line for a more extensive distribution system.

When it is necessary selected VHF channels at the output of the Model I Univertor may be phase locked to an off-the-air TV channel to minimize the visible affects of local TV channel interference. Since these problems are different for each locale, the phase lock feature is customized to meet the requirements of each installation

MODEL II UNIVERTOR

The frequency translation scheme of the MODEL II UNIVERTOR is depicted in Figure 5 Here two input cables with television channels and one with FM are provided at the input to the converter Conversion is accomplished with three Block Converters Cable No 1 has five television channels on it with a 4 MHz spacing between the 3rd and 4th channel When properly block converted this input spectrum translates to the Low VHF Band Television Channels 2 through 6. Cable No 2 has seven television channels on it in a contiguous spectrum between 6 and 48 MHz. When properly block converted this input spectrum translates to the High VHF Band television Channels 7 through 13 Cable No. 3 carries the FM radio band between 15 and 35 MHz and, as in Model 1, is block converted to the 88-108 MHz band The output multiplexing is similar to the Model I Univertor and provides twelve standard VHF television channels plus FM radio at the same output drive capability as the Model I Univertor.

The MODEL II UNIVERTOR output is compatible with the standard television set and no set-top converters are required by the customer. Two MODEL I or MODEL II UNIVERTORS are required for dual 12 channel capability.

MODEL III UNIVERTOR

The frequency translation scheme of the Model III Univertor is depicted in Figure 6. Here four input cables with television channels and one with FM radio are provided at the input to the converter. Conversion is accomplished with five block converters. The Low VHF Band is handled in the same manner as the Model II Univertor. The next three cables with seven TV channels per cable are block converted to provide the Mid-Band, High-Band and Super-Band television channels A through N and 7 through 13.

Again FM radio is block converted as described in the Model I Univertor. The output multiplexing is also similar to the Model I Univertor and provides 26 channels of TV plus FM at the same drive capability as this Univertor.

The Model III Univertor is compatible with most existing 26 channel step tuned set-top converters.

MODEL IV UNIVERTOR

The Model IV Univertor frequency translation scheme, depicted in Figure 7, is identical to the Model III Univertor except that the converters for the Mid-Band and Super-Band channels are arranged so as to invert these channels. In this manner the output of this Univertor provides 26 channels of television that is compatible with the tunerless style of set-top convert

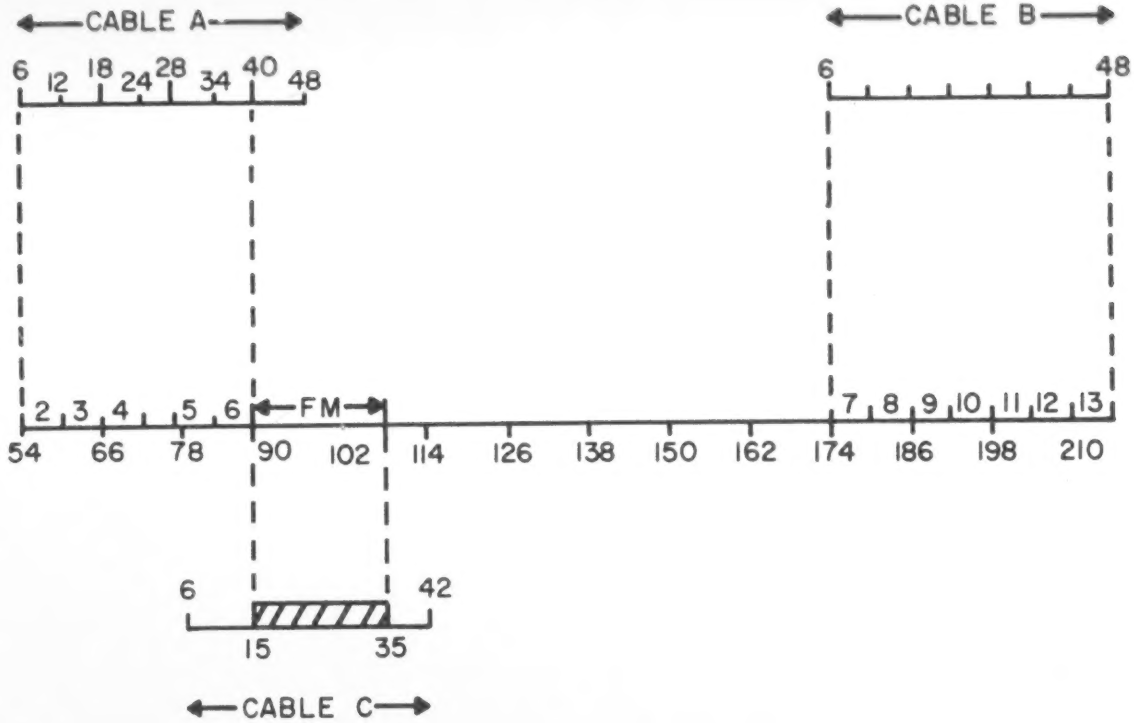
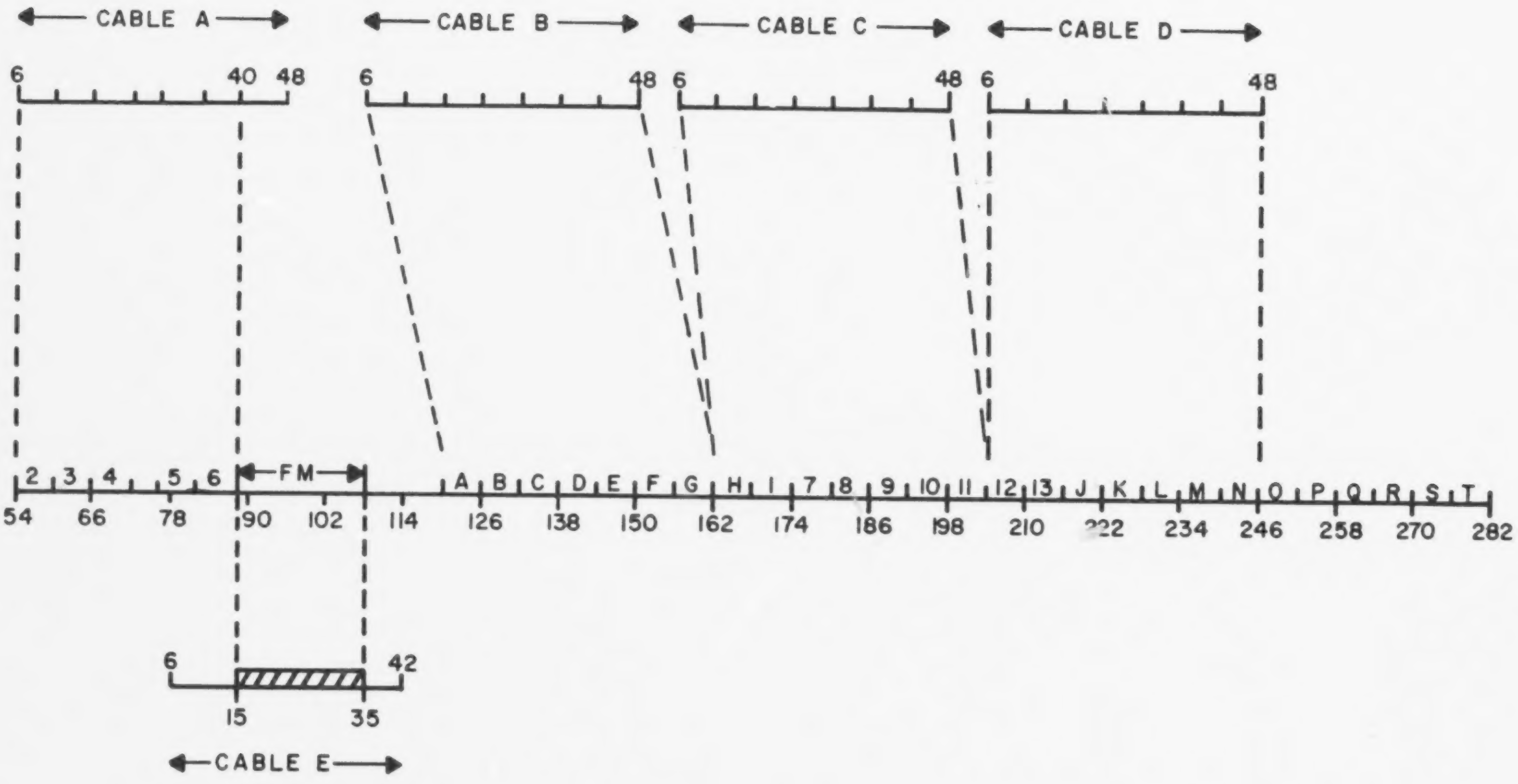
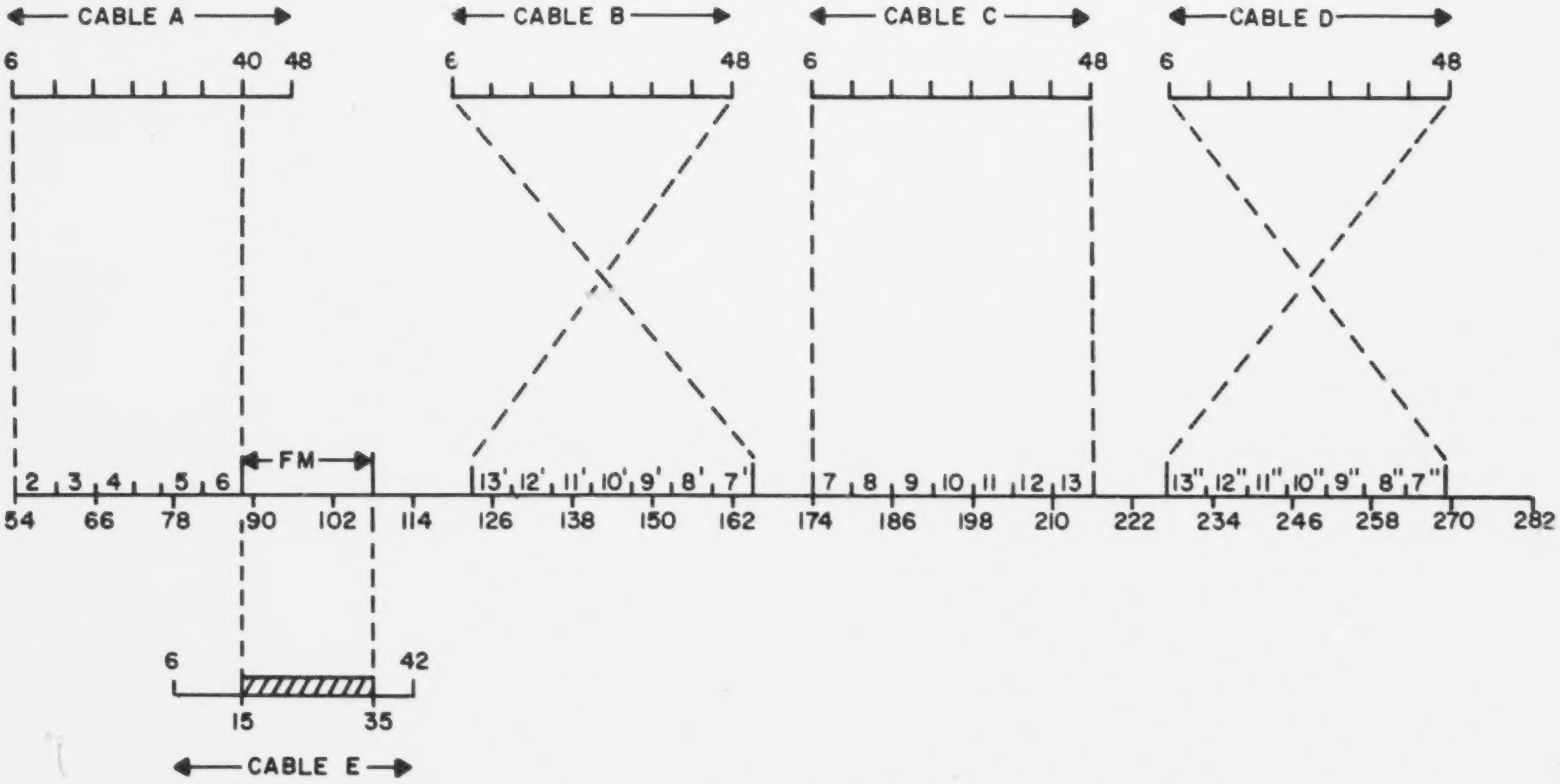

CABLE A
6
12
18
24
28
34
40
48
CABLE B
6
48
2
3
4
5
6
FM
7
8
9
10
11
12
13
54
66
78
90
102
114
126
138
150
162
174
186
198
210
6
42
15
35
CABLE C

FIGURE 5 – FREQUENCY TRANSLATION – UNIVERTOR, MODEL II


CABLE A
CABLE B
CABLE C
CABLE D
6
40
48
6
48
6
48
6
48
2
3
4
5
6
FM
A
B
C
D
E
F
G
H
I
7
8
9
10
11
12
13
J
K
L
M
N
O
P
Q
R
S
T
54
66
78
90
102
114
126
138
150
162
174
186
198
210
222
234
246
258
270
282
6
42
15
35
CABLE E

COMPATIBLE WITH TUNED SETTOP CONVERTER

FIGURE 6 - FREQUENCY TRANSLATION—UNIVERTOR, MODEL III


CABLE A
6
40
48
CABLE B
6
48
CABLE C
6
48
CABLE D
6
48
2
3
4
5
6
FM
13'
12'
11'
10'
9'
8'
7'
7
8
9
10
11
12
13
13"
12"
11"
10"
9"
8"
7"
54
66
78
90
102
114
126
138
150
162
174
186
198
210
222
234
246
258
270
282
6
42
15
35
CABLE E

COMPATIBLE WITH TUNERLESS SETTOP CONVERTER

FIGURE 7 – FREQUENCY TRANSLATION-UNIVERTOR, MODEL IV

Electrical performance characteristics of a Univertor insofar as overall signal to noise ratio and cross modulation are concerned are approximately equivalent to one Bridger amplifier. Therefore, the affect of the Univertor on system performance will be minimal. Exact performance characteristics for a particular system may be calculated using the detailed specifications for the Univertors as tabulated in Appendix "A"

AREA DISTRIBUTION CENTER & CHANNEL SELECTOR

Two additional basic building blocks used in FLEXICADE are the Area Distribution Center (ADC) and the Channel Selector. These units were originally developed by Ameco for their DISCADE system.

AREA DISTRIBUTION CENTER

The Area Distribution Center accepts up to 10 discrete coaxial cables at the input, and under control of the customers channel selector, electronically switches the customers drop cable to any one of these 10 lines; twenty-four customer drop cables are switched in each ADC housing. Ten of these ADC's may be cascaded to supply service for up to 240 customers from each bridger output. In this configuration the ADC looks like 240, single pole, 10 position electronic coax switches.

CHANNEL SELECTOR

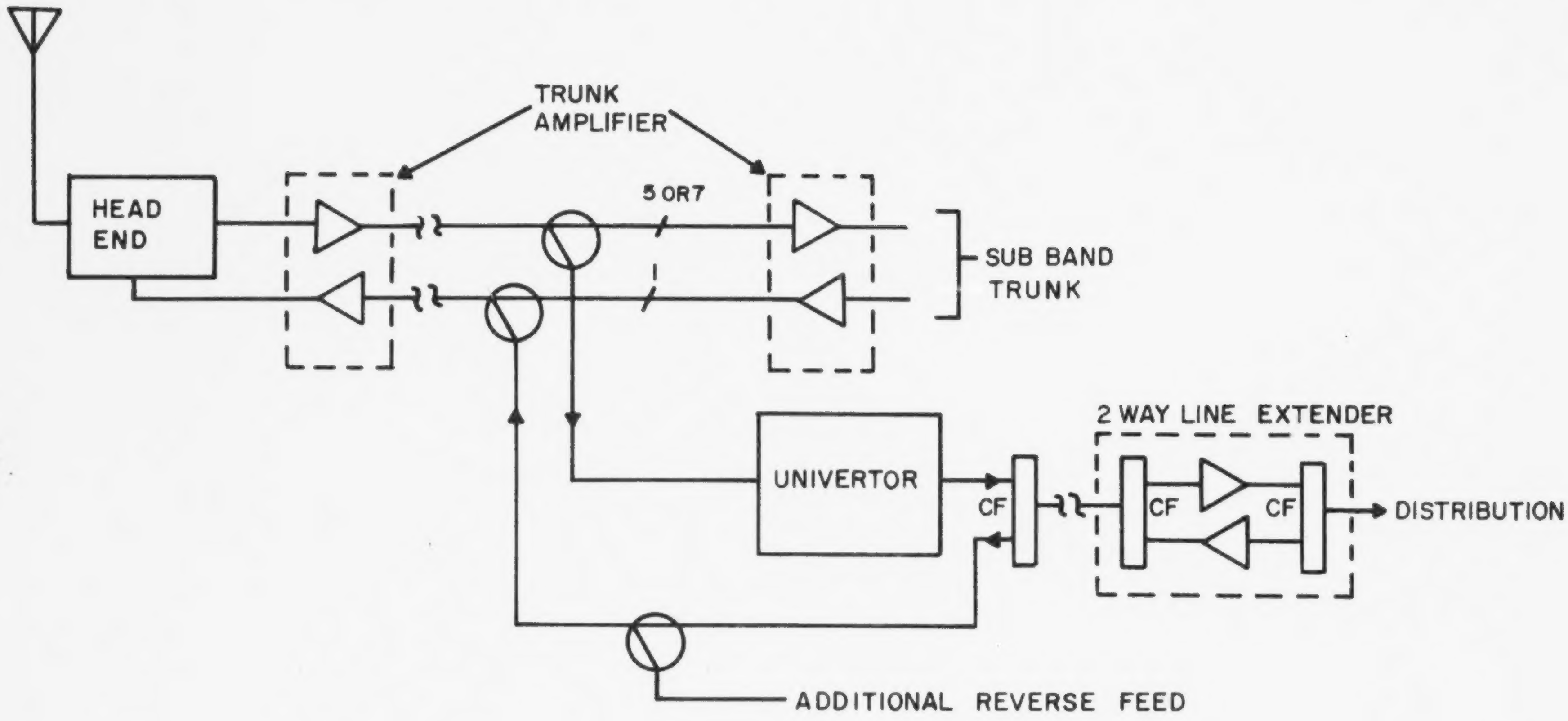
The channel selector is placed at the customers television set to interface between the cable system and the set. It contains the necessary switched converters to allow it to individually convert the four sub-band television channels on the customer drop cable back to a selected high VHF channel. Every fourth switch position of the channel selector interrogates the ADC and causes it to switch sequentially to another one of the input cables. With 10 cables carrying 4 television channels per cable at the ADC, the system is capable of providing up to 40 channels of television to the customer.

SYSTEM CONFIGURATIONS

Using the system elements just described various cable system configurations can be constructed, each of which offers certain advantages.

TYPE I SYSTEM

The first of these systems to be examined is the TYPE I system illustrated in Figure 8. This system configuration makes use of the Sub Nova amplifiers for a potentially long distance transportation trunk run. Strand mounted Univertors are coupled to the trunk at each distribution point in the system. In the simple distribution system the output of the Univertor is coupled directly to the customer distribution lines. In the more complex case the Univertor may drive a distribution trunk.


TRUNK
AMPLIFIER
HEAD
END
5 OR7
SUB BAND
TRUNK
2 WAY LINE EXTENDER
UNIVERTOR
CF
CF
CF
DISTRIBUTION
ADDITIONAL REVERSE FEED

OUTPUT—DUAL 12 CHANNELS OR 26 CHANNEL TV PLUS FM

FIGURE 8—TYPE I SYSTEM CONFIGURATION—UNIVERTOR MODEL I, II, III, OR IV
CONVENTIONAL ENTERTAINMENT WITH REVERSE FEED

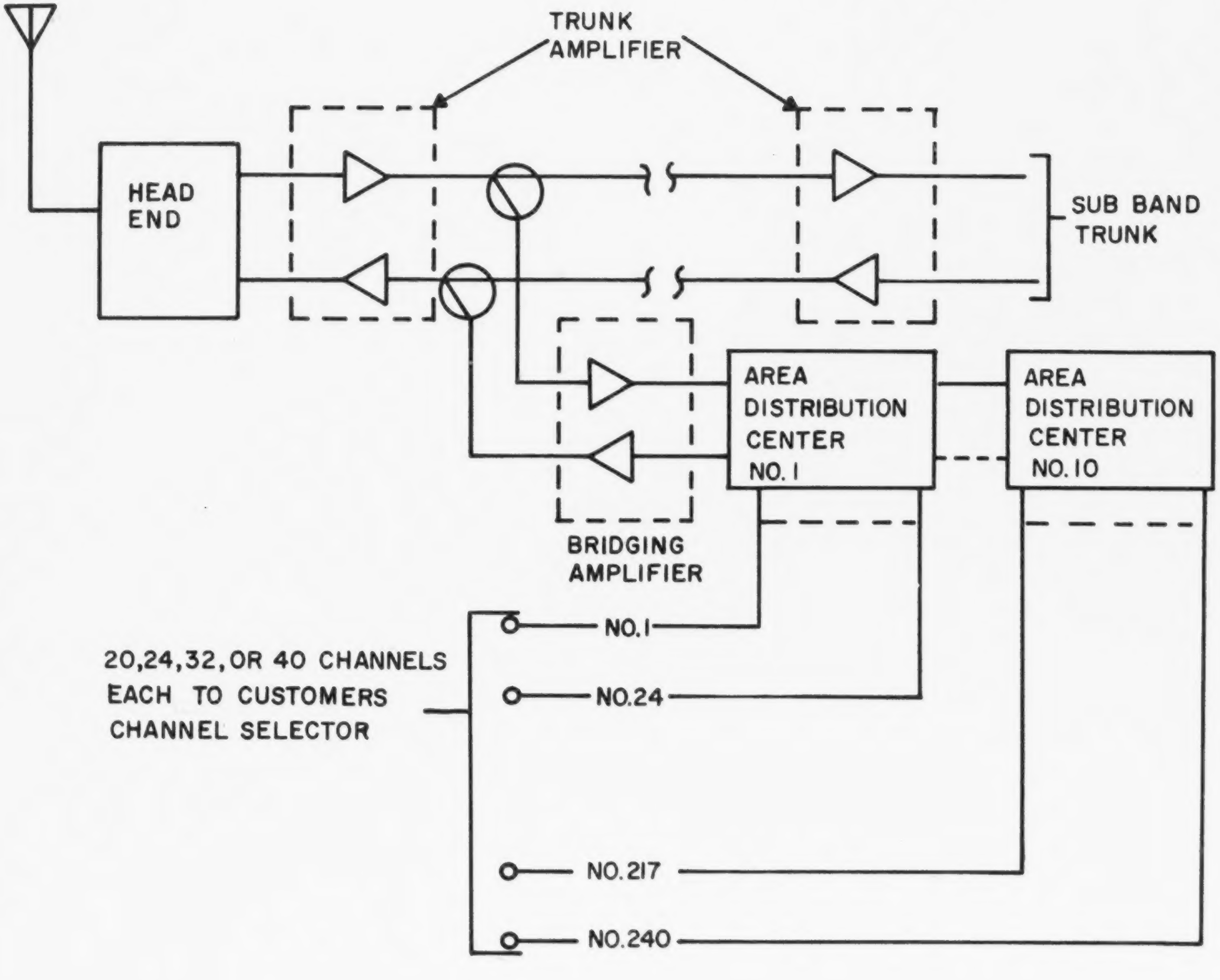
In this latter case Pilot Carrier generators are included in the Univertor to provide the Pilot Carriers for AGC Trunk Amplifier level control. Since any one of the MODELS I, II, III or IV UNIVERTORS may be used, several output options are available including, single 12 channel, dual 12 channel and 26 channel television. The 26 channel version, described earlier, is compatible with most standard set-top converters. In all cases FM radio can be included, if desired

Reverse feed capability is provided by a separate coax cable and Sub Nova trunk amplifiers. In this manner, up to 7 television channels are available in the reverse direction on a single cable. In systems where high quality reverse channel capability will be provided on all channels, the reverse cable can and should be entirely separate from the forward distribution system. However, in cases where reverse feed capability directly from the customer home is desired, the NOVA 2-way line extender amplifier illustrated can be used to provide this capability and still use the balance of the 7 channels for high quality special customer service. Since the distribution line amplifier cascade will normally be limited to a maximum of four line extender amplifiers, the TV channels that are run through these 2-way line extenders will encounter a worst case group delay distortion of less than 120 nanoseconds as a result of the complementary filters in this distribution line.

TYPE II SYSTEM

The second basic FLEXICADE system to be examined is the TYPE II system illustrated in Figure 9. One of the prime purposes of this system is to provide a cable system that can operate in the high ambient signal environments found in large metropolitan areas. To accomplish this objective it is necessary that the television channel never be carried on the cable at the same frequency as one of the local channels Therefore, in the TYPE II system, instead of converting the sub-band frequencies on the trunk back to VHF for distribution the signals are distributed by multiple discrete coax exactly as they are carried on the trunk This is accomplished as illustrated with the use of directional couplers, bridging amplifiers and the Area Distribution Centers to supply the sub-band television channels directly to the channel selector at the customer's television set. The channel selectors are customized for a particular installation to provide the converted VHF signal to the television set on one of the unused high band channels. In this manner the television channels are never carried in the system on the same frequency as the interfering local signals.

For those who are familiar with Ameco's hardware development activity this TYPE II system is Ameco's DISCADE system expanded to 4 channels per cable and updated to use the new push-pull amplifiers. As a result, the techniques and hardware of this system have been tried and proved in actual service.


TRUNK AMPLIFIER
HEAD END
SUB BAND TRUNK
BRIDGING AMPLIFIER
AREA DISTRIBUTION CENTER NO. 1
AREA DISTRIBUTION CENTER NO. 10
NO. 1
NO. 24
NO. 217
NO. 240
20, 24, 32, OR 40 CHANNELS EACH TO CUSTOMERS CHANNEL SELECTOR

COMBINED SYSTEMS

In most large metropolitan areas the cable system requirements will vary from area to area within the city. In one locale the prime problem may be high density housing with attendant strong interfering signal levels.

In another, more suburban area, these problems may not exist at all. A system designed to meet the criteria in one area may be completely unsuitable for application in another area served by the same operator.

FLEXICADE system components can be combined in various ways to provide acceptable solutions to all of these requirements. Figure 10 illustrates a very simplified combination of a TYPE I and TYPE II system that is designed to serve a high density industrial/commercial complex as well as a more remote suburban area. In this illustration, a local control hub serves to provide a switching center, remote from the Head End, which will allow the operator to adapt the system capabilities to meet the variable services that will be demanded by a dynamic commercial market.

The system illustrated provides the very flexible two-way services of the TYPE II system for the commercial services where high ambient local signals would be expected. On the other hand for the regular home entertainment services the TYPE I system with dual 12 channel output capability provides a very acceptable grade of service. In this manner set-top converters are not required for the large population of customers in the homes. Channel selectors would be required by those served by the TYPE II system, but this would only be for the relatively few commercial customer served.

A system with the basic principles of the one described above is presently in the first phases of construction by AMECO.

APPLICATION OF FLEXICADE

The most comprehensive application of the FLEXICADE system to date has been a cable system proposed to LVO, in Tulsa, Oklahoma, to meet the franchise requirements for that city. The capabilities of the system design reflects some of the potential that can be achieved using FLEXICADE system components in combination with conventional equipment.

SYSTEM DESCRIPTION

In laying out the FLEXICADE system design the city is divided into four major geographical regions with a neighborhood programming and distribution hub placed central to each area, see Figure 11. A fifth Neighborhood Hub is located adjacent to a Main Central Distribution Center. Each neighborhood is a self contained cable television system with its own receiving antennas for local television stations and provisions for receiving up to four distant microwave signals. Each Neighborhood Hub can originate one channel of television for distribution within its neighborhood or to other neighborhoods.

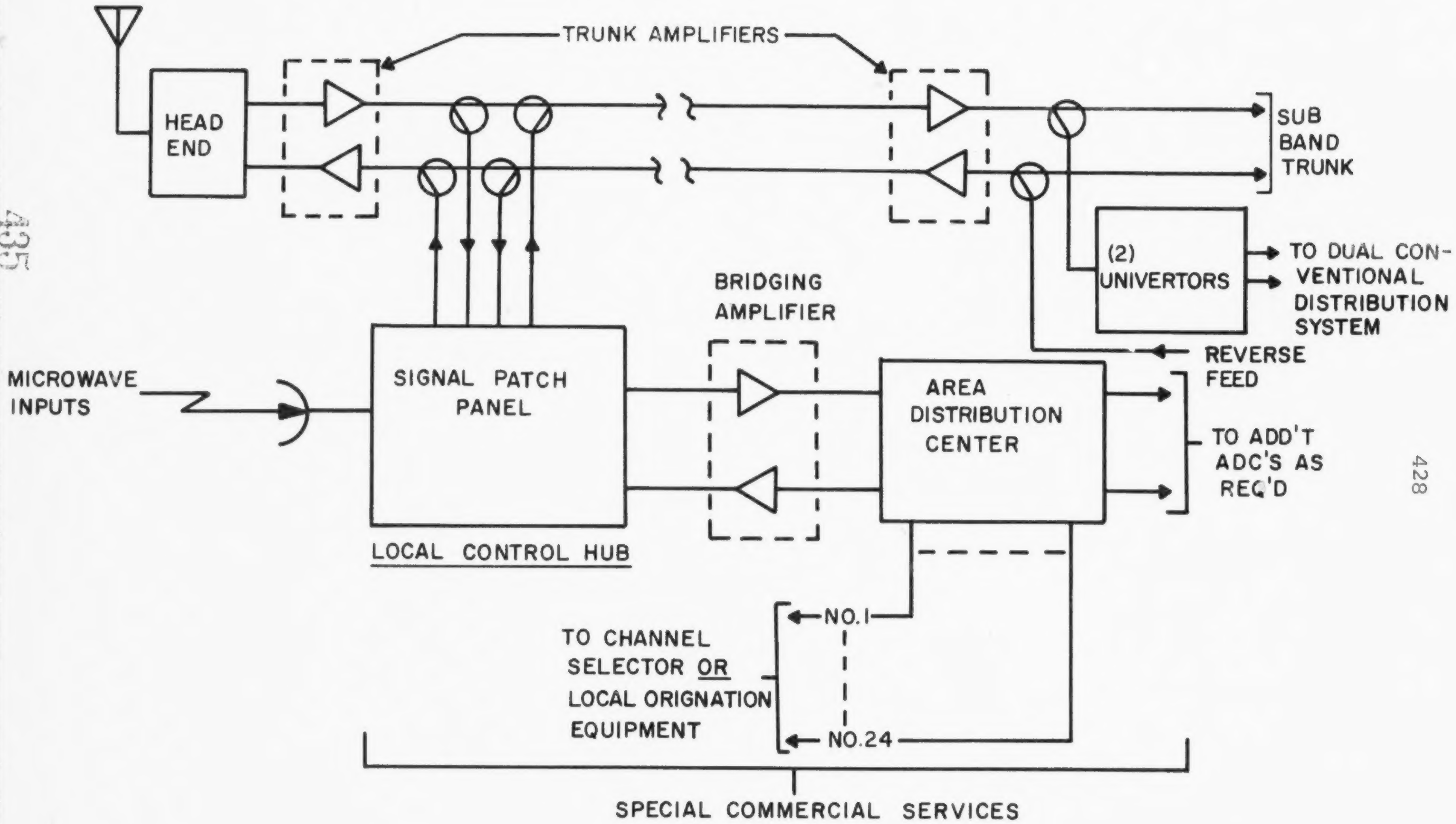

TRUNK AMPLIFIERS
HEAD END
SUB BAND TRUNK
(2) UNIVERTORS
TO DUAL CONVENTIONAL DISTRIBUTION SYSTEM
BRIDGING AMPLIFIER
MICROWAVE INPUTS
SIGNAL PATCH PANEL
REVERSE FEED
AREA DISTRIBUTION CENTER
TO ADD'T ADC'S AS REQ'D
LOCAL CONTROL HUB
NO.1
TO CHANNEL SELECTOR OR LOCAL ORIGNATION EQUIPMENT
NO.24
SPECIAL COMMERCIAL SERVICES

FIGURE 10 - COMBINATION, TYPE I & TYPE II SYSTEM - FLEXICADE WITH INDUSTRIAL/COMMERCIAL CONTROL CENTER

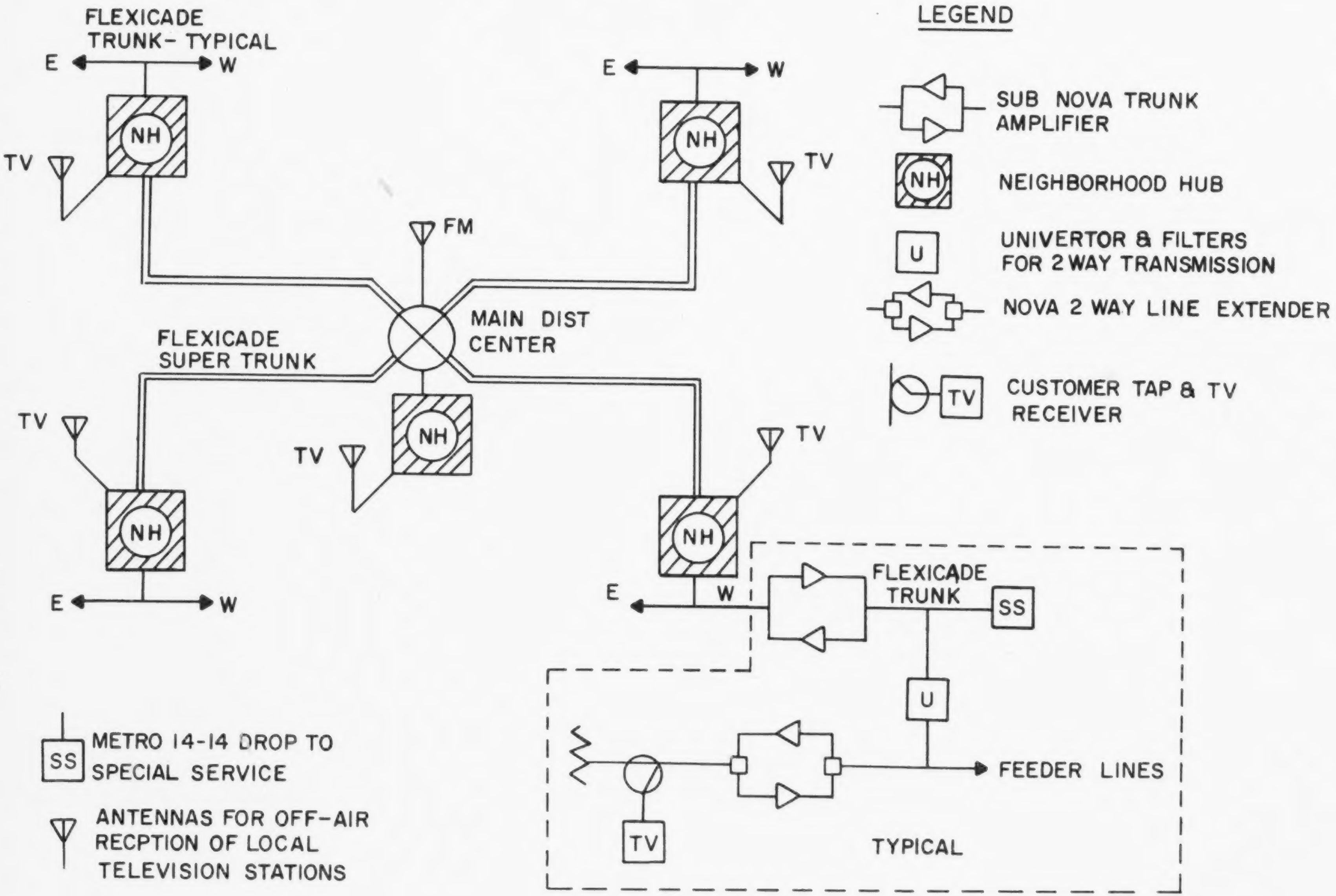

FLEXICADE TRUNK- TYPICAL
E
W
TV
NH
FM
MAIN DIST CENTER
FLEXICADE SUPER TRUNK
FLEXICADE TRUNK
SS
U
FEEDER LINES
TYPICAL
LEGEND
SUB NOVA TRUNK AMPLIFIER
NEIGHBORHOOD HUB
UNIVERTOR & FILTERS FOR 2 WAY TRANSMISSION
NOVA 2 WAY LINE EXTENDER
CUSTOMER TAP & TV RECEIVER
METRO 14-14 DROP TO SPECIAL SERVICE
ANTENNAS FOR OFF-AIR RECPTION OF LOCAL TELEVISION STATIONS

FIGURE 11— OVERALL SYSTEM CONCEPT

The system supplies two services in parallel. The Primary System supplies entertainment, educational and information television to the general public in the home via low frequency FLEXICADE trunk, Univertors and a convention feeder system. This system has return signal capability on the feeder lines for transporting television signals and data to the FLEXICADE trunk which returns these signals to the central office on a separate cable.

A second set of trunk cables, lashed to the same messenger and following the same trunk routing as the Primary System trunk cables will provide the second service called the METRO 14-14 service. This second service provides very high quality wide-band signal transportation between business, educational, medical and government institutions and can be patched to and from the Primary System as needed.

This second trunk will be connected by short branch trunks as required to all the key points and will deliver 14 outbound channels to these key points in addition to and completely separate from the 33 Primary System channels carried on the regular subscriber drop. In addition, 14 inbound or returning channels will be provided on this METRO 14-14 system to distribute television or data information originating at any key point to any Neighborhood Hub, or to the Main Distribution Center for switching to any point in the system. Access to the METRO 14-14 system is through Univertors or special customized single channel converters when secure channels are desired.

The Main Distribution Center will provide all signals for the Primary outbound channels except those originated at the Neighborhood Hub. Patching facilities here permit routing any program material originated on the METRO 14-14 or returned from the Primary System feeder lines to be rerouted to any or all points in the system.

The Main Distribution Center is coupled to the Neighborhood Hubs by a long haul sub band high quality super trunk. The outputs of the Neighborhood Hubs are high quality sub band trunk lines that are coupled to Univertors for frequency conversion and distribution of the Primary service to the general public.

The details of signal multiplexing and switching are illustrated in a Block Diagram of the Neighborhood Hub, Figure 12, and are left as an exercise to the interested reader.

The spectrum utilization in this system is illustrated in Figure 13. Seven cables make up the Primary system, six of these handle outbound information, the seventh handles the 5-30 MHz inbound television and data from the feeder system. The six outbound cables provide the capability for a total of 33 channels of television plus FM radio. Twenty-six of the channels are planned for entertainment, educational and information television services, the remaining seven channels of spectrum space is available for special television services and data communications.

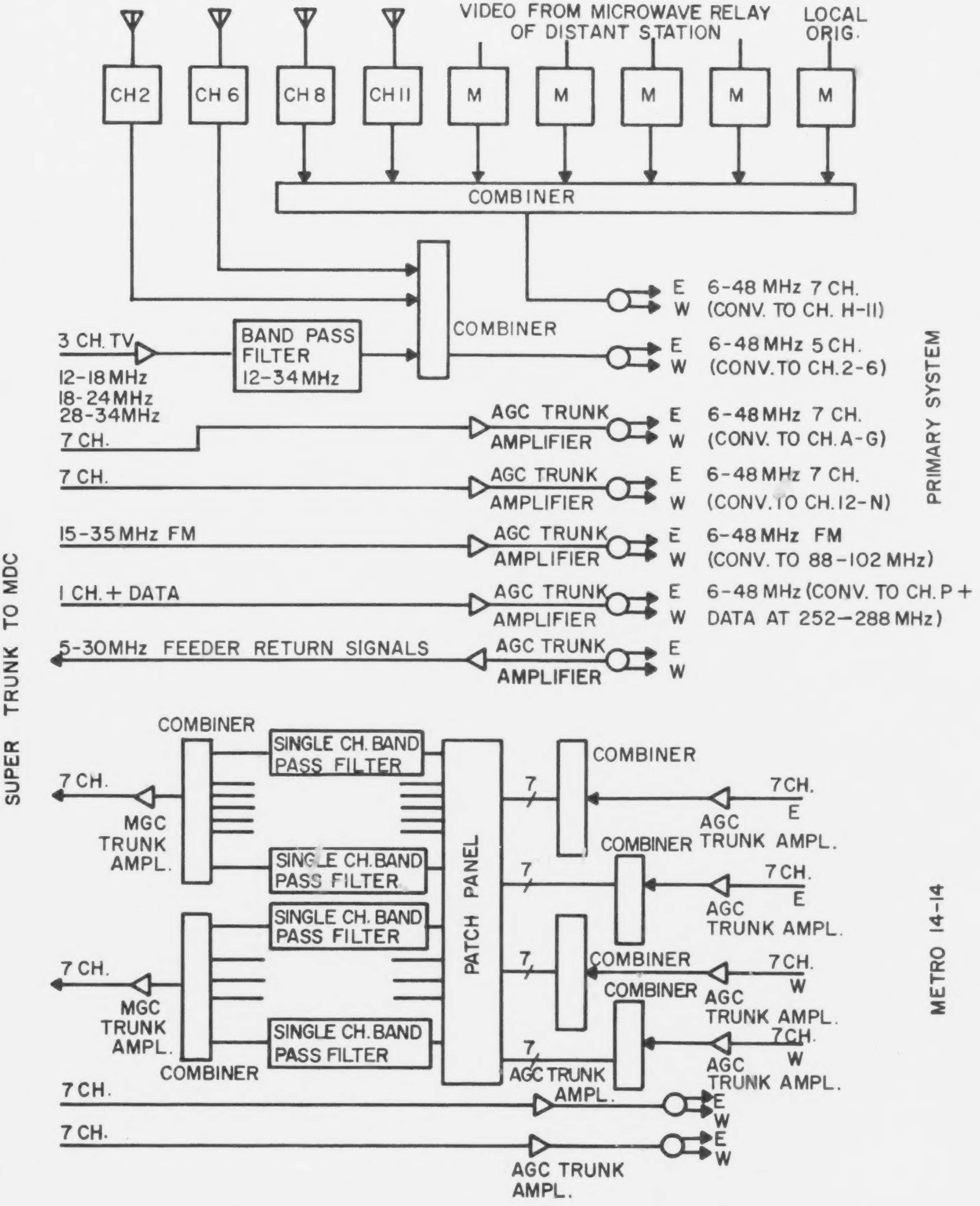

VIDEO FROM MICROWAVE RELAY OF DISTANT STATION
LOCAL ORIG.
CH2
CH 6
CH 8
CH 11
M
M
M
M
M
COMBINER
COMBINER
3 CH. TV
12-18 MHz
18-24 MHz
28-34 MHz
BAND PASS FILTER 12-34 MHz
E
W
6-48 MHz 7 CH. (CONV. TO CH. H-11)
E
W
6-48 MHz 5 CH. (CONV. TO CH. 2-6)
7 CH.
AGC TRUNK AMPLIFIER
E
W
6-48 MHz 7 CH. (CONV. TO CH. A-G)
7 CH.
AGC TRUNK AMPLIFIER
E
W
6-48 MHz 7 CH. (CONV. TO CH. 12-N)
15-35 MHz FM
AGC TRUNK AMPLIFIER
E
W
6-48 MHz FM (CONV. TO 88-102 MHz)
1 CH. + DATA
AGC TRUNK AMPLIFIER
E
W
6-48 MHz (CONV. TO CH. P + DATA AT 252-288 MHz)
5-30MHz FEEDER RETURN SIGNALS
AGC TRUNK AMPLIFIER
E
W
PRIMARY SYSTEM
SUPER TRUNK TO MDC
COMBINER
SINGLE CH. BAND PASS FILTER
7 CH.
MGC TRUNK AMPL.
SINGLE CH. BAND PASS FILTER
SINGLE CH. BAND PASS FILTER
7 CH.
MGC TRUNK AMPL.
SINGLE CH. BAND PASS FILTER
COMBINER
PATCH PANEL
7
7
7
7
COMBINER
7 CH.
E
AGC TRUNK AMPL.
COMBINER
7 CH.
E
AGC TRUNK AMPL.
COMBINER
7 CH.
W
AGC TRUNK AMPL.
COMBINER
7 CH.
W
AGC TRUNK AMPL.
AGC TRUNK AMPL.
7 CH.
E
W
7 CH.
AGC TRUNK AMPL.
E
W
METRO 14-14

FIGURE 12-NEIGHBORHOOD HUB

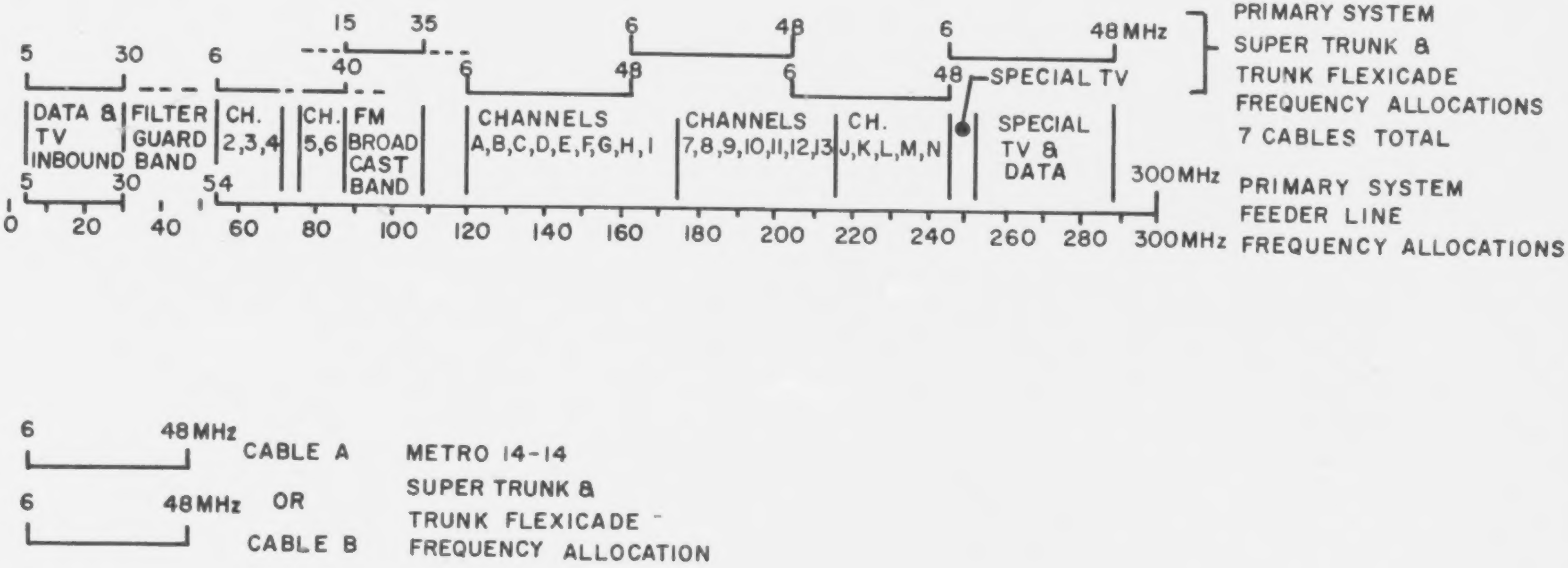

15
35
6
48
6
48MHz
5
30
6
40
6
48
6
48
SPECIAL TV
PRIMARY SYSTEM
SUPER TRUNK &
TRUNK FLEXICADE
FREQUENCY ALLOCATIONS
7 CABLES TOTAL
DATA & TV INBOUND
FILTER GUARD BAND
CH. 2,3,4
CH. 5,6
FM BROAD CAST BAND
CHANNELS A,B,C,D,E,F,G,H,I
CHANNELS 7,8,9,10,11,12,13
CH. J,K,L,M,N
SPECIAL TV & DATA
5
30
54
300MHz
PRIMARY SYSTEM
FEEDER LINE
FREQUENCY ALLOCATIONS
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300MHz
6
48MHz
CABLE A
OR
6
48MHz
CABLE B
METRO 14-14
SUPER TRUNK &
TRUNK FLEXICADE -
FREQUENCY ALLOCATION

FIGURE 13 – FREQUENCY ALLOCATION CHART

The Univertor Hubs convert the sub band signals on each cable to the spectrum space allocated on the feeder cable between 54 and 300 MHz.

The return line provides 25 MHz of system capacity from each and every subscriber drop to the Neighborhood Hub and on to the Main Distribution Center. This 25 MHz bandwidth will be divided into one television channel and 19 MHz of bandwidth for data communications. This spectrum is strictly "party line". The television channel is not intended for use by subscribers, but as a quick method for remote program relay back to the Main Distribution Center.

The 28 TV channels for the Metro 14-14 facility are carried on four coax cables on sub band frequencies directly to the customer.

In summary the FLEXICADE system for Tulsa would provide a total of 58 television channels plus FM radio and 19 MHz of data bandwidth in a very flexible arrangement that would meet the requirements for this city's franchise.

The features of this system that are considered noteworthy are:

1. There are no directional filters in any part of any trunk or super trunk, hence no filter guard bands need be allocated on the trunks.

2. Normal outbound channels to all subscribers go through filters only on the feeder cables which maintains group delay at a very low level.

3. The METRO 14-14 inbound signals return on cables separate from the 5-30 MHz data/remote TV signals so no interference between the two is possible.

4. The complete cable communications system is an enclosed non-radiating system which does not require a transmitter license; therefore, FCC restrictions are minimized. Signal format is not as restrictive as Microwave Systems.

5. Standard cable television test equipment, test methods, and techniques are employed throughout the system. There is no need for special test equipment or specially trained personnel.

6. The low frequency long haul FLEXICADE system holds signal degradation to a minimum by minimizing the cascade of amplifiers.

CONCLUSION

The FLEXICADE hardware and system concepts that have been described here do not provide solutions to all of the myriad of problems that the systems designer faces. However, they do add a substantial new dimension to his "bag of tools" that will help him to meet the new demands that will be placed on him by the expanded market place.

REFERENCE:

[1]/ Hickman, J.E. and Kleykamp, G.C.
"Multi-Cable Solutions to Communications Systems Problems", presented to the IEEE CONVENTION, March, 1971, New York, N.Y.

APPENDIX "A"

DETAILED ELECTRICAL AND MECHANICAL SPECIFICATIONS

I SPECIFICATIONS - SUBNOVA TRUNK AMPLIFIER

FREQUENCY RESPONSE	(W/O Equalizer)	2-48 MHz
RESPONSE FLATNESS	2-48 MHz	± .25 dB
	6-48 MHz	± .15 dB
MINIMUM FULL GAIN	(W/O Equalizer)	30 dB
OPERATING GAIN	(W/ Equalizer)	26 dB
*NOISE FIGURE @MIN. FULL GAIN (W/O Equalizer, f=43.25 MHz)		7.5 dB MAX
RETURN LOSS, IN/OUT	2-48 MHz	18 dB
	6-48 MHz	20 dB
CROSS MODULATION	4 Ch, 5 dB Block Tilt	-90 dB @+36 dBmV
	7 Ch, Tapered Tilt	-85 dB @+36 dBmV
SECOND ORDER BEAT		-76 @+36 dBmV
HUM MODULATION		-65 dB
AGC RESPONSE	(±3 dB of Cable)	± .25 dB
SLOPE RANGE, MANUAL		± 3 dB Cable
GAIN RANGE, MANUAL		0-9 dB
RECOMMENDED OPERATING CHARACTERISTICS:		
INPUT @HIGHEST VISUAL CARRIER		+10 dBmV
OUTPUT @HIGHEST VISUAL CARRIER		+36 dBmV
AMPLIFIER SPACING (W/ APPROPRIATE EQUALIZER)		17-26 dB
POWER REQUIREMENTS		21V @ 450 MA
PILOT CARRIER FREQUENCIES		7.25 & 37.25 MHz
OPERATING TEMPERATURE RANGE		-40°F to +140°F
CABLE EQUALIZATION RANGE (W/ plug-in Equalizers)		8-26 dB
FLAT GAIN		9-0 dB
SIZE - Individual Amplifier		2"(W) x5"(H) x10 1/4"(L)
Housing with (8) amplifiers & power supply (Exclusive of mating connectors and mounting hardware)		7 1/2"(W) x12 1/2"(H)x22 3/4"(L)

*Noise Figure @Operating Gain, w/ equalizer (f=43.25 MHz, Cable = 68°F) 8.5 dB

II SPECIFICATIONS - MARK II CHANNELEER

ELECTRICAL

Recommended input (picture carrier):	0 to +10 dBmV
Recommended output: Visual carrier	+54 dBmV
Aural carrier	+38 dBmV
Maximum input range (picture carrier):	-14 dBmV +30 dBmV
Minimum input (sound carrier):	-24 dBmV
AGC control:	±0.5 dB output change for an input change from -14 dBmV to +30 dBmV
Output level control:	12 dB range (video-to-audio ratio constant)
Signal to noise Ratio:	59 dB Min. @+6 dBmV input
Return loss input/output:	16 dB (75 ohms)
Image rejection:	60 dB minimum
Adjacent channel carrier rejection:	50 dB minimum
Local oscillators:	Crystal controlled
Video IF response:	41.57 MHz to 46.50 MHz, ±0.25 dB
Carrier substitution oscillator:	45.75 MHz, crystal controlled carrier
Spurious signals:	60 dB below desired output from 6 to 300 MHz
Power requirements:	95 to 130 VAC, 60 Hz, 30 Watts

MECHANICAL

Physical dimensions:	19 x 17 x 5 - $^{1}/4$ inches
Weight:	19 pounds

III SPECIFICATIONS - UNIVERTOR

ELECTRICAL

Input - (See Channel frequency assignments in Figure 1)

MODEL I: 3 Cables with Channels A1, A4, A5 and A6
MODEL II: 2 Cables - one with Channels, A1, A2, A3, A4', A5'
one with Channels A1, A2, A3, A4, A5, A6, A7

MODEL III & IV: 4 Cables - one with Channels A1, A2, A3, A4', A5'
three with Channels A1, A2,A3,A4,A5, A6, A7

ALL MODELS: 1 Cable (optional) with FM from 15 to 35 MHz and
Pilot Carriers at 7.25 MHz and 37.25 MHz

Reference Pilot Carriers as may be required for specific Channel phase locking.

LEVEL: + 10 dBmV ± 3 dB

RETURN LOSS: 16 dB Minimum (75 ohms)

NOISE FIGURE: 13 dB Nominal

Output

MODEL I: 12 Channels of TV, CH. 2-13
plus FM Radio at 88-108 MHz
(if FM option specified)

MODEL II: Same as Model I

MODEL III: 26 Channels of TV, CH. 2-13 and
Channel A thru N - compatible
with tuned set-top converter, plus
FM at 88-108 MHz (if FM option specified).

MODEL IV: 26 Channels of TV, CH. 2-13 and Channels 7M thru 13M (Mid Band channels,); Channels 7S thru 13S (Super Band channels) - compatible with tunerless set-top converter, plus FM at 88-108 MHz (if FM option specified).

-Pilot Carrier Generator (optional) - supplied as part of FM converter.

LEVEL:	+32 dBmV with Block Tilt 5 dB - 12 channels +32 dBmV with Block Tilt 32/30/28/25 - 26 channels +40 dBmV output optional available with reduced C.M. characteristics.
CROSS MODULATION:	(-) 72 dB @+32 dBmV output - 12 channels (-) 70 dB @+40 dBmV output - 12 channels (-) 70 dB @+32 dBmV output - 26 channels (-) 66 dB @+40 dBmV output - 26 channels
RETURN LOSS:	- 16 dB minimum (75 ohms)

MECHANICAL

HOUSING:	7 1/2" (W) x 12 1/2 " (H) x 22 3/4 " (L) Exclusive of mating connectors and mounting hardware
OPERATING TEMPERATURE RANGE:	-40°F to +140°F

PHASE LOCKING CAPABILITY

PURPOSE:	To provide a method for phase-locking an output VHF channel to an off-the-air channel to minimize effects of Co-channel interference.
METHOD:	A pilot carrier, phase locked to the off-the-air channel is supplied to the Univertor for phase-lock reference.
AVAILABILITY:	On special order: most channels can be accommodated.
ADDITIONAL EQUIPMENT REQUIREMENTS:	One special unit is required at the head end to derive the pilot carrier reference for each off-the-air channel, regardless of the number of Univertors in the system.

RELIABILITY THROUGH TOTAL AUTOMATION OF CATV SYSTEM DESIGN

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I. INTRODUCTION

Within the past few years Network Analysis Corporation's computer CATV design service has established itself as the most economical CATV system designer in existence. Repeated comparisons, contests and competitions against individual designers, manufacturers and system owners of all sizes and varieties have confirmed the economy of NAC's computer designs; examples of these savings are well documented.[1-4] However, we often encounter the mistaken notion that these hardware savings are made by, in some sense, sacrificing reliability or flexibility inherent in human design. Logical appraisals of the question, and all available experience indicate the contrary. In fact, this notion indicates a serious lack of understanding of what constitutes a "good" design. Because of the increasing complexity in new system designs, such a misconception can have disasterous consequences for the system owner. Therefore, with some examples we will illustrate how the system owner obtains a significantly more reliable design, with more flexibility for system modification and expansion, and with better overall control of his design process--through use of NAC's computerized CATV system design service.

II. INCREASED RELIABILITY AND FLEXIBILITY THROUGH AUTOMATIC DRAFTING

To augment its CATV design service NAC has recently completed an automated drafting program. With this new feature, layouts developed by NAC's design program are drawn as complete final construction maps by an automatic drafting machine under direct command of the computer. With this drafting program the system owner is now able to achieve levels of reliability, control and flexibility previously unavailable in the industry; the automated plotter provides another bonus for using NAC's design service. The specific advantages of automatic drafting are numerous:

1. Elimination of Drafting Errors. One time-consuming factor in the past has been the drafting and checking of maps. Once a human is introduced into the design-drafting process, errors are introduced and hence there is a need for a long checking process. To check a typical 100-mile system for every tap value and location, as well as all amplifiers, power supplies etc. takes a checker about one week, and still drafting errors slip by. With the

automatic plotter,the layout is drafted exactly as designed. The net result is less headaches for construction crews and better systems for owners.

2. Faster Layouts. The 10-mile system shown in Figure 2 was drafted by the computer in 15 minutes, including all linework symbols and lettering. A typical 100-mile system is drawn automatically at 200' to the inch, in about four hours of plotter time. In other words, the time to produce correct drawings has been reduced by a factor of 20 over the efforts of a draftsman and checker.

3. Complete Flexibility in Drawing Modifications. As any system designer knows, very few layouts remain untouched once they are completed. Strand changes are discovered. Telephone poles seem to move with a life of their own and people are found to live on unmapped streets. Often these sections are redesigned on the spot. The new information can then be fed to the program which will modify the appropriate sections of layout or redraw a whole map, or a whole system as the user wishes.

4. Complete Flexibility in Presentation. The computer can make the drawings to any scale. You may want one drawing at 200' to the inch and another overview drawing at 400' or 1000' to the inch. Instead of resorting to microfilm and photo reduction methods, the plotter will simply produce the required drawing. It can isolate any section of the design and draw it to any required scale. For example, it can break out the trunk routing as a separate drawing.

5. Complete Flexibility in Format. The program has a library of symbols that can be used for any particular device. If the system owner wishes a different symbol, it can easily be added to the library. At present we have all the NCTA standard symbols in the library as well as many variations of these symbols in use by our clients. Thus, for example the symbols for trunk bridgers and directional couplers shown in Figure 3, are all in the library, even though the last symbol for the trunk bridger is not a standard NCTA symbol.

In summary, automated drafting produces its results faster than humans without introducing drafting errors. The system owner does not have to choose speed or reliability; he gets speed and reliability.

III. INCREASED RELIABILITY AND FLEXIBILITY THROUGH COMPUTER DESIGN

One of the most persistent misconceptions fostered by manual designers is that they "overdesign" a system by putting extra amplifiers in so that they have more reliability and more slack for flexibility. This is absolutely false. There is indeed extra equipment and more cost. But, obviously, with more electronics there are more failure-prone elements in the system and less overall reliability.

For example, the design in Figure 4.a. shows an industry manual design for one section of a larger 100-mile system. The computer design for the same section is shown in Figure 4.b. The manual design has 4 more extender amplifiers than the computer design. Furthermore, there are 3 places where there are 3 extenders in cascade in the manual design whereas there are none in the computer design. The computer design is obviously more reliable. In general, if reliability data is available for different types of amplifiers, such as trunk and extender amplifiers, the computer will take them into account trading off amplifiers for the best design.

The claims for added slack and flexibility in manual designs also turn out to be patently false upon examination of the available evidence. As an example, the minimum input level to extender amplifiers in the design in Figure 4 was 20dBmV. For the computer design, signal levels are high enough so that the feeders could be extended or taps could be added if necessary without adding extender amplifiers. In the manual design, some of the end levels are tighter even though there are more amplifiers. Furthermore, the computer designed system is easier to expand or change because there are only two extenders in cascade.

The net result is that the manual design with more electronics is, in every sense, a poorer design--more expensive, less reliable and less flexible. The manual design has wasted electronics which in no sense adds to the system performance--only the system cost. The way to improve system reliability is to first adopt more rigid system specifications. With computerized design, it is actually possible to design to significantly tighter specifications with no additional cost over a more poorly performing manual design.

Reliability in Meeting Design Specifications

In addition to drafting errors and poor designs, one of the primary hazards of manual designs to system owners, builders and users are good old-fashioned errors and blunders. Sometimes these are errors in bills of materials, but more often, and more seriously they are technical errors which make the system unreliable, or indeed, incapable of meeting contractual specifications.

The types of errors made by manual designers, of course, include every possible error that can be made. Some of the more prevalent and representative types that we have come across are shown in the examples below. Needless to say, the computer cannot make these errors.

a. Signal levels at subscriber taps. In the portion of the industry design shown in Figure 5, the output levels of the taps are given. The required tap output level is 10 dBmV. Note that on one tap the signal level is 3 db too low--the customer is receiving only one half his required signal power. This is one of the most persistent types of industry fudges. In one industry design the signal at over 20% of the taps did not meet the required output level. With proper design this type of fudge is unecessary.

b. Trunk spacing. In Figure 6 is an industry design in which the required 22db trunk spacing is exceeded by .97 db. Errors on the trunk of this sort are truly unfortunate since the resulting distortion propagates throughout the remainder of the system. In major markets where cable signals are competing with off-the-air pickup, the resulting poor quality pictures are particularly serious.

c. Power requirements. Figure 7 shows an industry design with 6 extender amplifiers drawing power from one output of a trunk bridger amplifier thereby exceeding the power passing capability of the bridger. This means that subscribers will not be getting decent service until a section of the system is rebuilt.

Our experience has shown that these types of errors occur repeatedly in manual designs. Why are there so many errors in layouts produced by industry designers? There is probably no single reason although there are obviously many critical factors.

The quality of designers in the industry varies greatly. A designer with five years experience is usually superior to a designer with one year of experience. With the rapid turnover of designers and the rate of introduction of new lines of equipment many designers don't get much experience with particular equipment. With those that do, the "Peter Principle" takes its toll: good designers don't usually end up being good designers --they end up being managers. So the really good people are probably not doing your design. For example, in tests that we have seen, one manufacturer ran the same system through ten designers and had a 15 percent variation in cost among his own staff. As another example, for our tiny 1971 NCTA Convention contest system of 2.9 strand miles there was a 17% variation in cost among the entries of the human designers and 35% of them were incorrect because of significant errors either in the bill of materials or actual design. This shows just how inconsistent the output of a designer really is.

The time factor is also critical. The contest winners told us they had spent 50 hours to design the three-mile system. When a professional designer tells you he designs five to ten miles a day, you should suspect that you are not getting the best design. For example, in many cases the designers may realize that to properly eliminate an extender amplifier that is a few hundred feet from the end of a feeder would require some straightforward but laborious manual redesign. Rather than do this, he will eliminate the amplifier anyway by cheating on some tap outputs and the system owner gets an inferior system.

If the situation is bad now, there are indications that it will become worse. If the recent FCC rulings lead to a spurt in construction, the present designers are clearly going to be swamped. The typical design will be even poorer and may take longer to produce. The FCC decision makes the computer not only a useful tool but a vital one. It's a lot easier to manufacture twice as much equipment as it is to create twice as many good designers and designs. If manufacturers and MSO's were to try to staff up to handle the new volume, the lack of training and experience of the new designers would only magnify their existing difficulties due to normal time pressures and unfamiliarity with new equipment.

IV. INCREASED CONTROL THROUGH NAC'S COMPUTER CATV DESIGN

Because of its speed, reliability and flexibility, NAC's CATV design service offers the system owner more control of his system through a more precise and complete understanding of his system cost and performance. This applies at every stage--proposal, system design and system construction.

1. Proposal. NAC's design service enables an MSO bidding for a franchise to obtain fast, accurate and reliable bills of materials. Repeated designs can be made for different lines of equipment, different head end locations, different population densities and different trunk routings. The computer can generate several bills of materials and the plotter can draft error-free, all parts of the design, such as trunk routing, to any desired scale for each design. Instead of having to rely on one partial design and rule of thumb estimates, the MSO can proceed with confidence that he has accurately evaluated all cost-performance tradeoffs.

Since the program and automatic plotter are so fast, they can be of great assistance at even the most preliminary stages of system evaluation. Suppose you have a street map, the locations of poles and an estimate of the number of houses to be fed from each pole --but you do not yet have a strand map. The computer will draw a best system design along with the strand map that goes with it. This strand can then be fed to the computer and the appropriate parts of the layout can be redesigned. Thus, the program is even useful in formulating a strand map.

If you do not have pole locations but the street map is drawn to scale or you have an aerial photograph, the program can design with poles spaced on an average pole span basis to obtain a dedicated design. Designs can be made for different population densities and saturations. Our experience has been that even if only the street map, estimated population densities and selected equipment line are given, the computer estimate of hardware cost is within 10% of the cost of the final design.

2. System Design. At the design stage the MSO has the assurance that he has the best design at every step and that it is free of design and drafting errors. Changes to the strand map or system requirements, can be fed to the computer and the design modified according to the current information. Because of the speed of the design process, the MSO can have a firm idea of his system progress at an earlier stage.

To do a computer design we input more data than needed so the computer can cross check the information. With this automated checking, the computer can produce designs in roughly a half to a third of the time that human beings would require. With most customers we have found that an acceptable arrangement is delivery of the first 100 miles in three weeks with each subsequent 100 mile section in two weeks. This fits in well with their construction and our production schedules. However, we work very closely with our clients and are responsive to their needs. If the system owner is rushed for a design, we can deliver 100 mile sections at the rate of one per week.

3. System Construction. Once the layout is completed and, for example, changes in strand occur there are several possible choices for handling it. (1) If the changes are extensive and nonlocal the data can be changed in a matter of minutes and the computer run to obtain a new design. (2) If the changes are localized, the computer redesign may be restricted to a portion of the layout. (3) If the changes are relatively minor, they can be fed to the program which will change the computer drawings. All these modes are made simply by the flexibility inherent in the computer design and drawing.

V. CONCLUSION

NAC has recently converted the output of its computer CATV design program to automatically drafted layouts. This automatic error-free drafting combined with the speed and reliability of the computer designs make NAC's computer CATV design service the most reliable and fastest CATV designer in existence--as well as the most economical.

REFERENCES

1) "A Computer Design of CATV Distribution Systems," Ivan T. Frisch, Bill Rothfarb, Aaron Kershenbaum, 20th NCTA Official Convention Transcript, July 6-9, 1971, Washington, D.C.

2) "A Computer Design of CATV Distribution Systems," Ivan T. Frisch, Bill Rothfarb, Aaron Kershenbaum, Cablecasting, Vol. 7, No. 5, July-August 1971, pp. 20-26.

3) "Network Optimization for Two-Way CATV System Design is Programmed on a Computer" in New Product Applications IEEE Spectrum, Vol. 8, No. 11, Nov. 1971, p. 82.

4) "Stranded in the Map Maze? A Computerized Way Out," Ivan T. Frisch, TV Communications, Vol. 9, No. 2, February 1972, pp. 34-42.

FIGURE CAPTIONS

1. A Calcomp plotter drawing a CATV layout under the control of NAC's Computer CATV design program.

2. A photograph of part of a 10 mile layout drawn at 200' to the inch by NAC's automated plotter. The automatic drafting time was 15 minutes.

3. Some of the symbols used by NAC's clients which are in NAC's computer library of sumbols. Others can be added easily.

4. Comparison of NAC's computer design with an industry manual design shows NAC's design more reliable because of fewer amplifiers --and with more slack and flexibility for modification and future growth. (a) An industry design. (b) NAC's computer design.

5. An industry manual design in which tap output levels do not meet specifications.

6. An industry manual design in which trunk spacing violates system requirements.

7. An industry manual design in which power passing capability of a trunk bridger amplifier is violated.

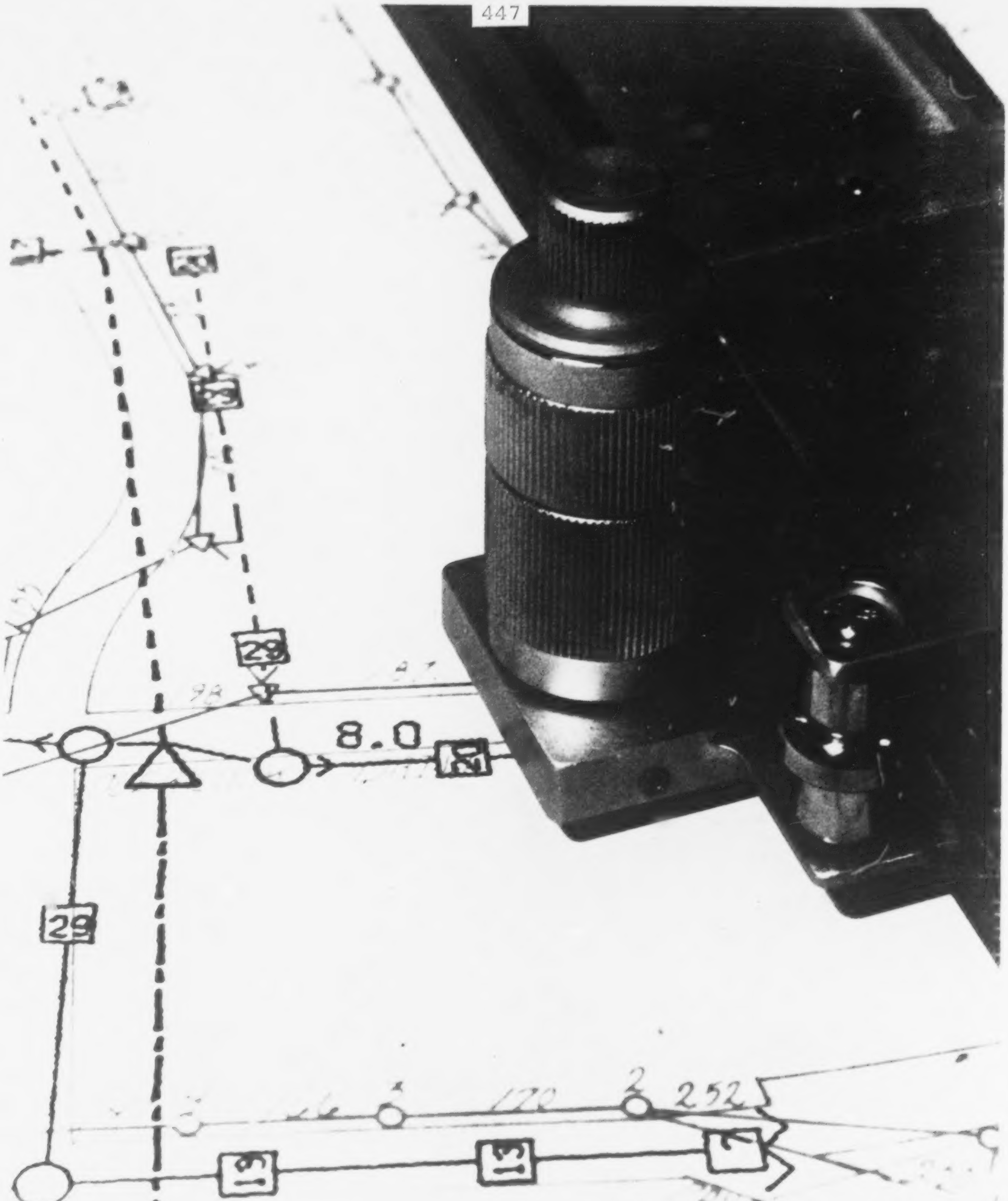
447
29
29
8.0
29
170
2
252

FIGURE 1

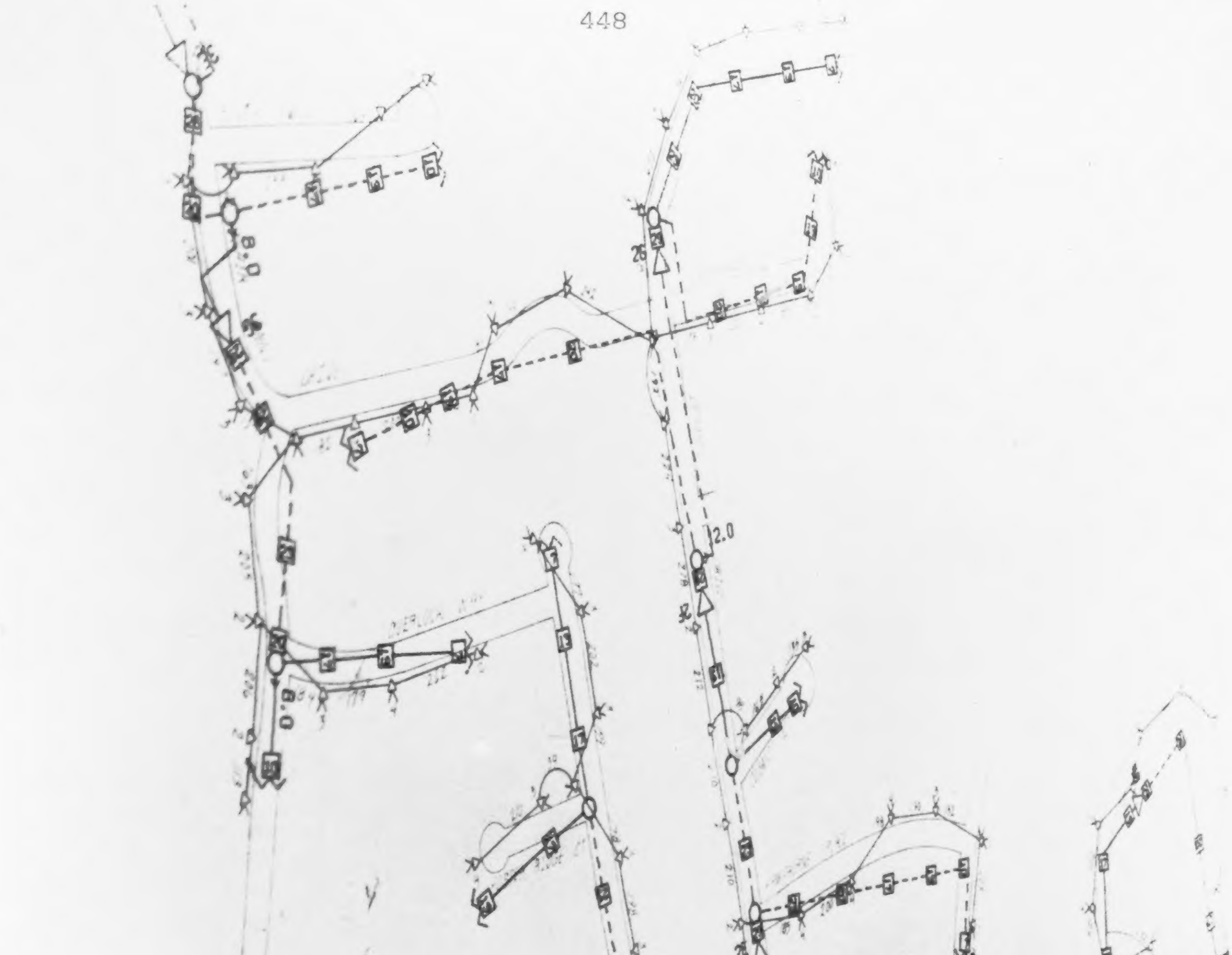
8.0
8.0
12.0
12.0
8.0
OVERLOOK DRIVE
BROOKDALE DRIVE

FIGURE 2

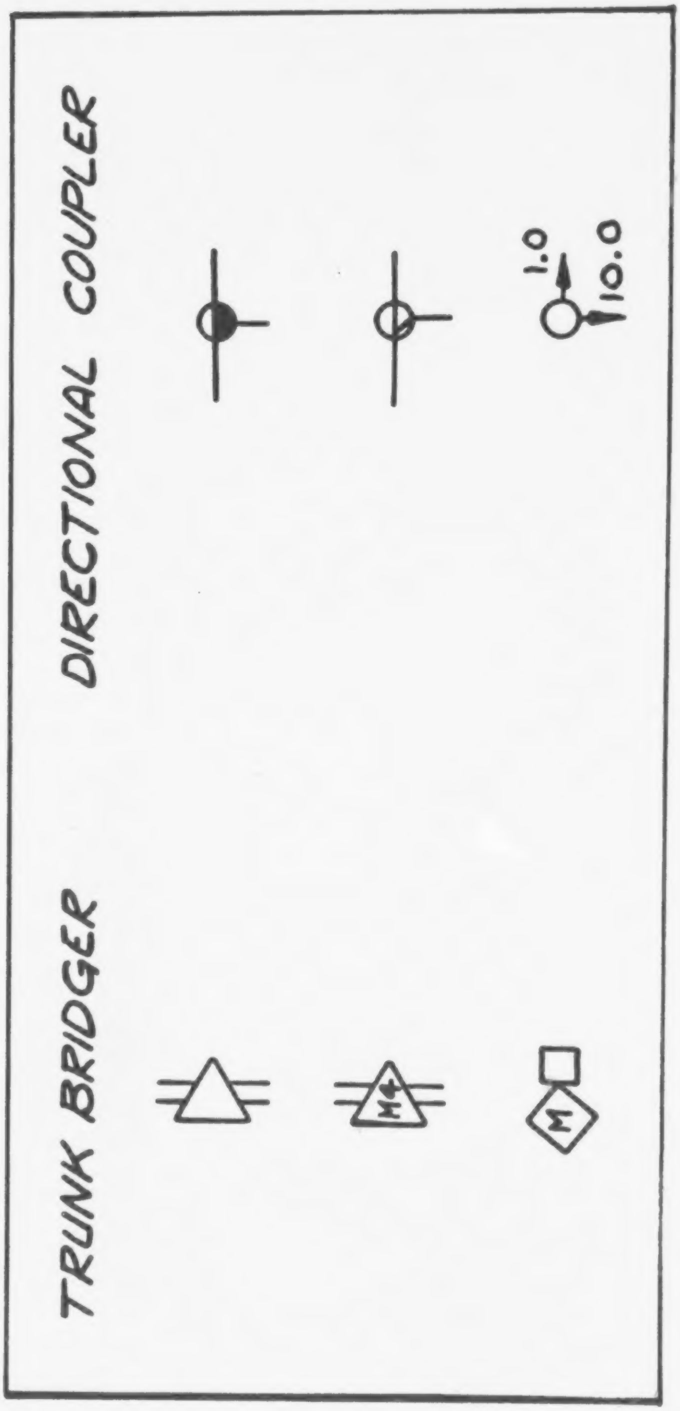
TRUNK BRIDGER
DIRECTIONAL COUPLER
1.0
10.0

FIGURE 3

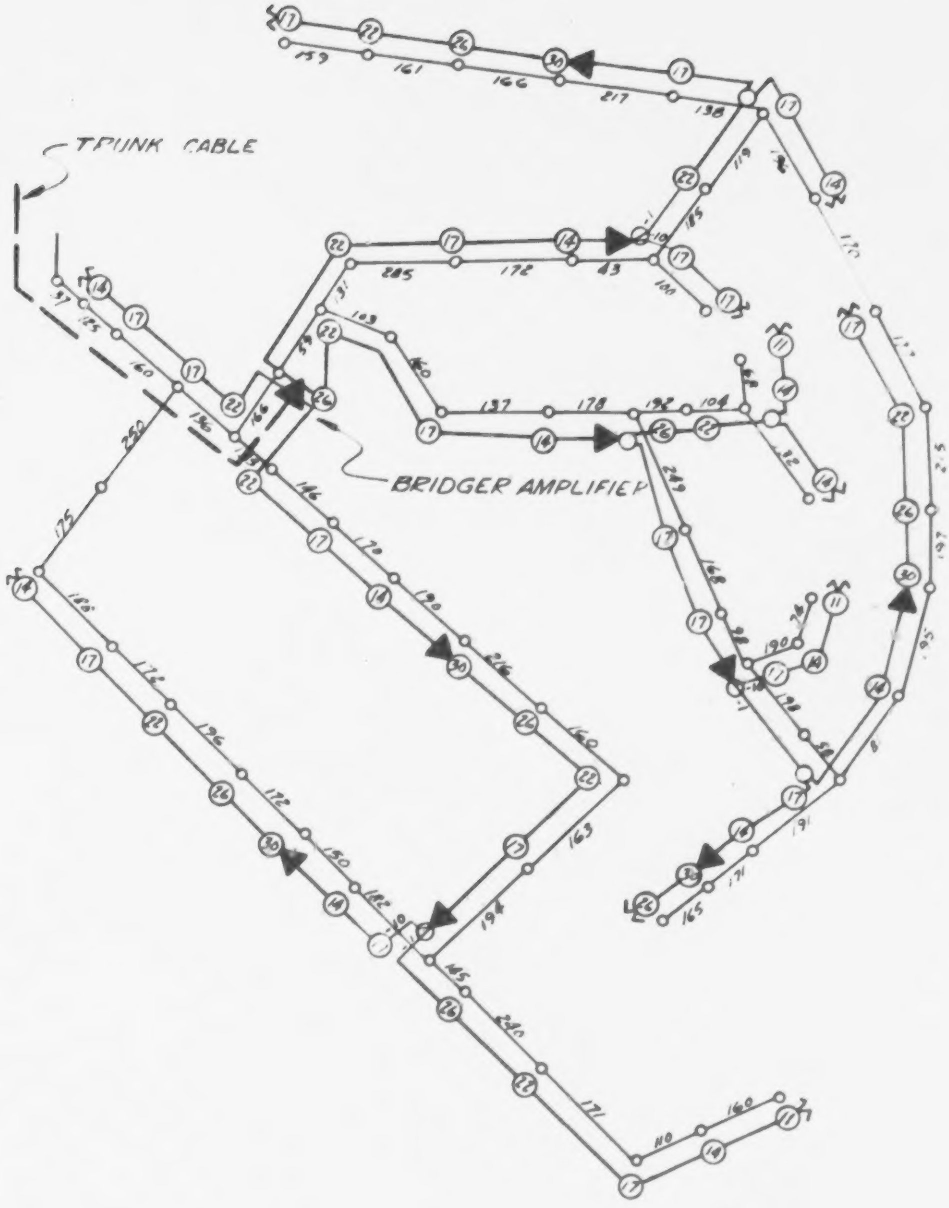
TRUNK CABLE
BRIDGER AMPLIFIER

FIGURE 4

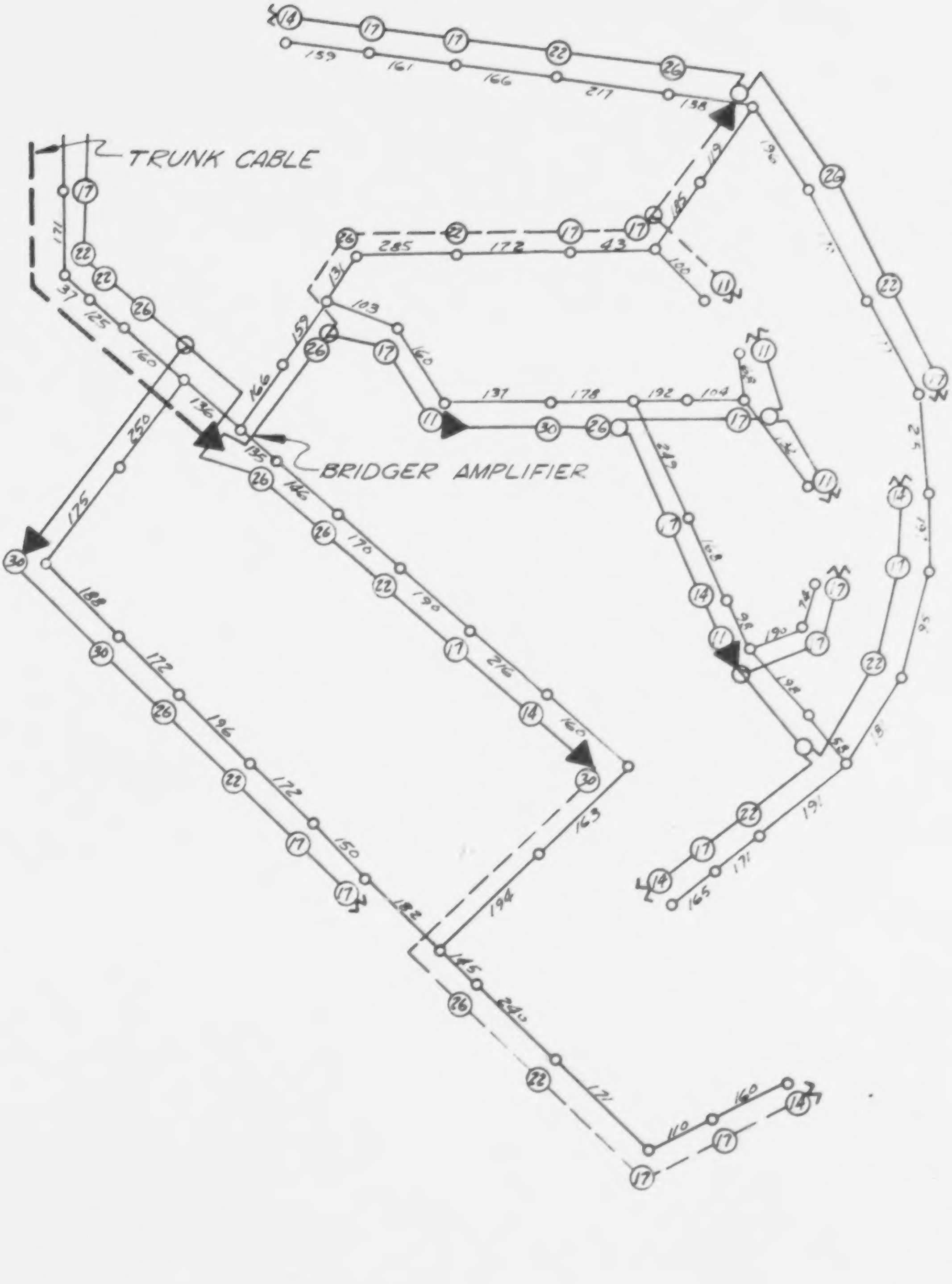
TRUNK CABLE
BRIDGER AMPLIFIER

FIGURE 4b

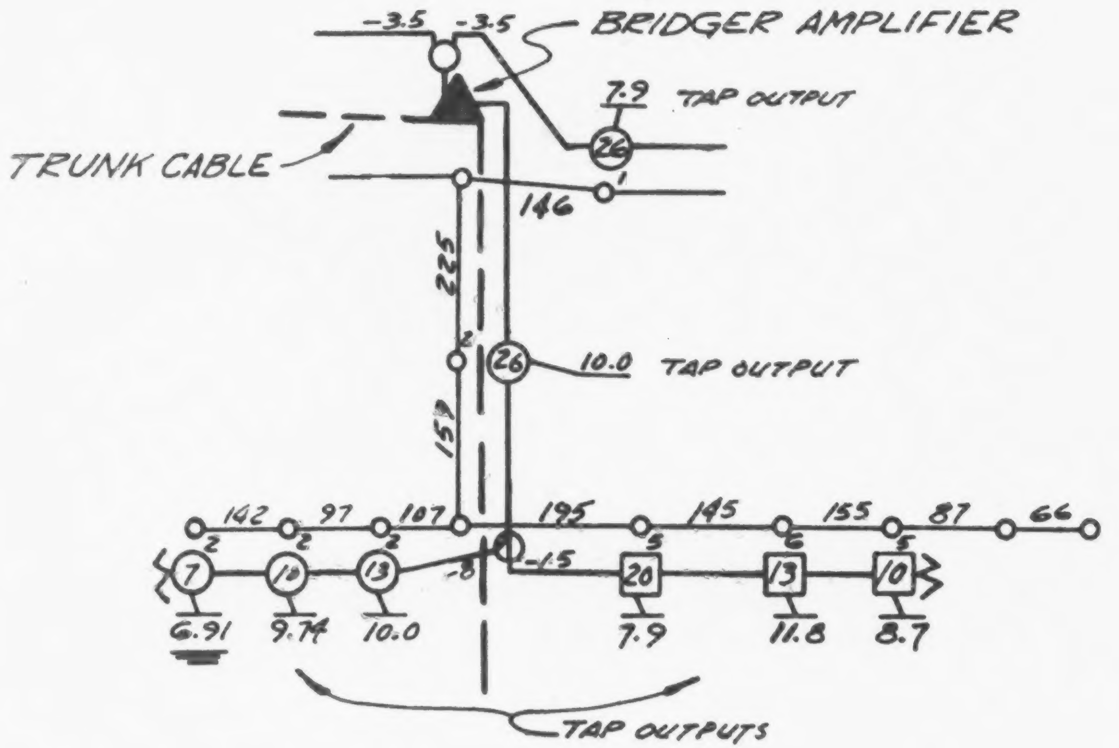
-3.5
-3.5
BRIDGER AMPLIFIER
7.9
TAP OUTPUT
26
TRUNK CABLE
1
146
225
2
26
10.0
TAP OUTPUT
159
142
97
107
195
145
155
87
66
2
2
2
5
6
5
7
10
13
-8
-15
20
13
10
6.91
9.74
10.0
7.9
11.8
8.7
TAP OUTPUTS

FIGURE 5

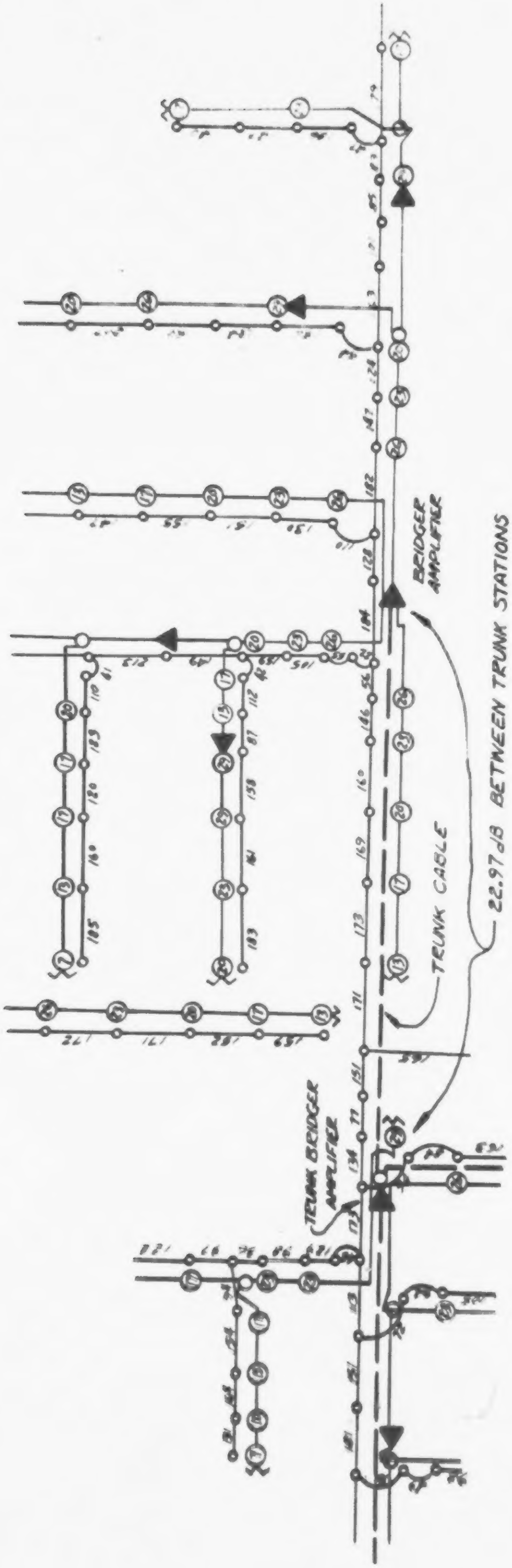
BRIDGER AMPLIFIER
TRUNK CABLE
22.97 dB BETWEEN TRUNK STATIONS
TRUNK BRIDGER AMPLIFIER

FIGURE 6

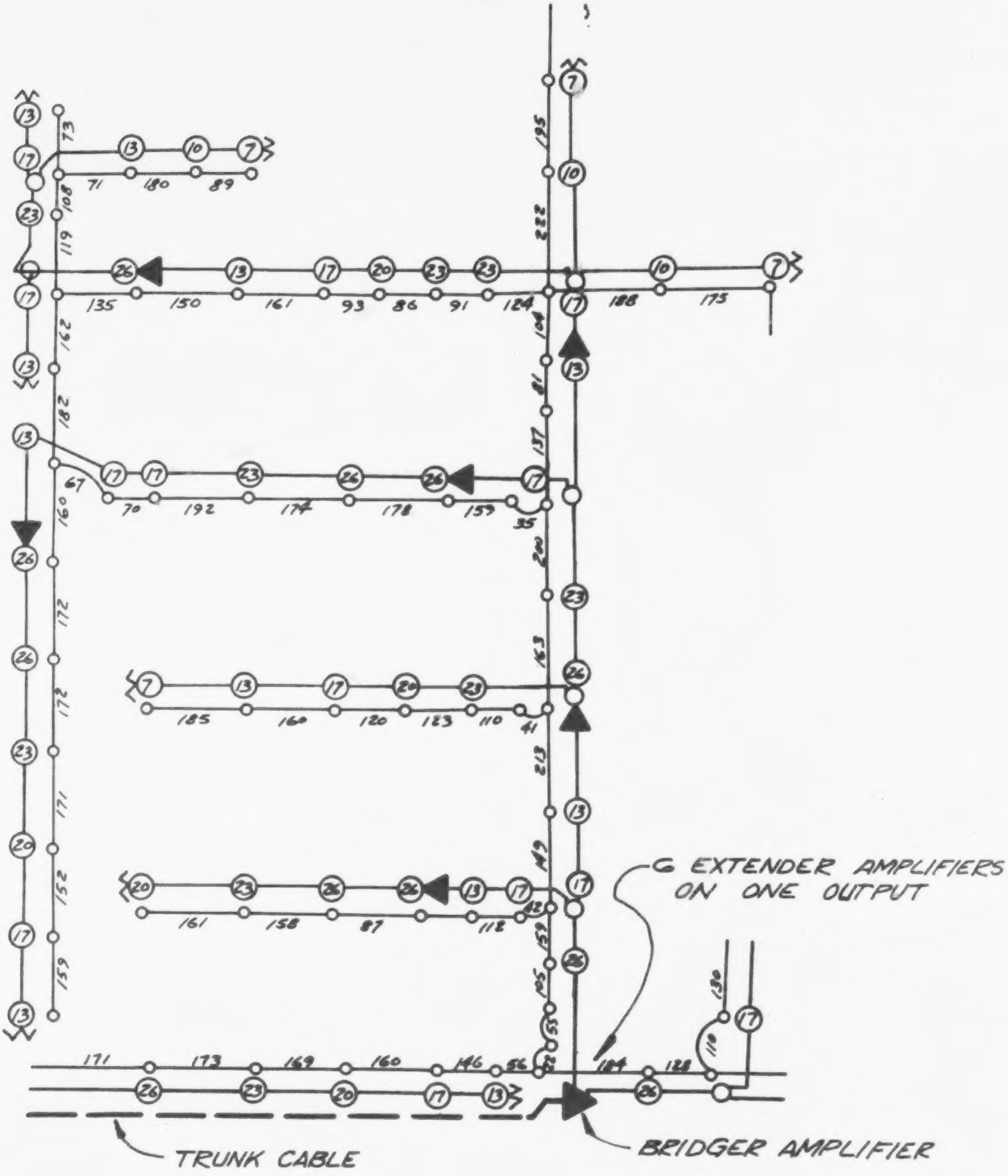
6 EXTENDER AMPLIFIERS ON ONE OUTPUT
TRUNK CABLE
BRIDGER AMPLIFIER

FIGURE 7

RETURN SYSTEM AGC IN TWO-WAY CATV SYSTEMS

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INTRODUCTION

I. This paper will examine the problem of automatic gain control (AGC) for the return direction in two-way systems. In contrast to the downstream direction where one or two pilots are distributed over the system, a return system will use a multiplicity of pilots. These pilots are injected at system extremeties and travel back to the head end unless prevented from so doing. The problems and desirability of stopping pilots is considered as applied to various types of pilot. The types of pilot considered include CW pilots, audio frequency modulated pilots, pilots with synchronized frequencies and also pilot control signals consisting of band limited white noise.

The problem of location of return pilot generators is examined along with the necessity for precise level control of all imput signals for the return system. The latter consideration becomes obvious when one realizes that the only reason for using automatic gain control in a system is to preserve the system tolerance, even if the automatic gain control performance in a system is perfect.

II. The AGC requirements for a two-way system in the forward direction are essentially the same as for a typical one-way system. The control signals normally used are CW pilot carrier, modulated pilot carrier, or an off air video signal. The choice is usually determined by system or equipment requirements.

In the forward direction, the signals entering the system can be tightly controlled at the head end and there is a known relationship between the levels of these signals and the pilot carrier levels. Since the signals all enter the system at a common point, the relationship between these signals remains constant at this point. If the system is designed so that the pilot carrier or carriers control both amplifier gain and tilt then the signal levels will remain constant relative to the pilot carrier level throughout the entire system.

In the return direction, however, the situation is not nearly so simple. Each trunk termination where return signals may be entering the system must be considered as a separate head end. Since the distance from the many various points of origination to a common point for both the return signals and the return pilot carriers are not the same, there is no fixed relationship between the levels of these signals and the levels of the return pilot carriers. Under these conditions, the return pilot carrier is primarily a system gain control. Level control must be achieved by other methods which will be discussed later.

Let us now look at the above mentioned signals which are typically used for AGC control in the forward direction and examine their adaptability as a reference signal for the return system AGC.

I. CW Pilot Carrier

Using a CW pilot carrier for AGC control in the return direction on a two-way cable system can cause a number of problems. In the forward direction one or two pilot carriers or control frequencies are chosen. These pilot carriers follow the many branches in the system outward and appear at the termination of every trunk branch.

In the return direction, however, a pilot carrier would have to be originated at many, if not all, of these branch terminations. Unless the frequency of these pilot carriers is precisely controlled from the head end, it is very unlikely that any two pilot carriers would have exactly the same frequency (±.005% for crystals frequently used in CATV equipment). Two different pilot carriers with slightly differing frequencies would be combined at a branch juncture. At the first AGC station following this branch junction there would be a 6db increase in pilot carrier level relative to the desired carrier levels. At every branch junction (a split in the forward direction) in the system, the total pilot carrier energy, assuming a peak detector in the AGC, would be the voltage addition of the pilot carrier signals in the two combining branches.

In addition, the combination of two pilot carriers differing slightly in frequency would appear effectively as a single side band modulated carrier with the frequency of modulation equal to the difference in frequency between the two pilot carriers. If the circuitry in the AGC were not capable of removing the modulation, it would be transferred to every other carrier passing through the amplifiers under control of that particular AGC circuitry.

Trapping out one of the carriers by 39db or more before combination would insure that the combination of the two carriers would be no more than .1db above the original pilot carrier level at every branch junction. Each pilot carrier junction would add an additional .1db to the pilot carrier level. This would prevent a rapid buildup of the pilot carrier level but would not completely solve the problem that the main pilot carrier which is not trapped out would be modulated by all the pilot carriers that were trapped out. In any event, attainment of 39db of trapping would be expensive and difficult to achieve. It would also introduce additional chroma delay into the system.

II. CW Pilot Carrier with the Frequency Controlled from the Head End

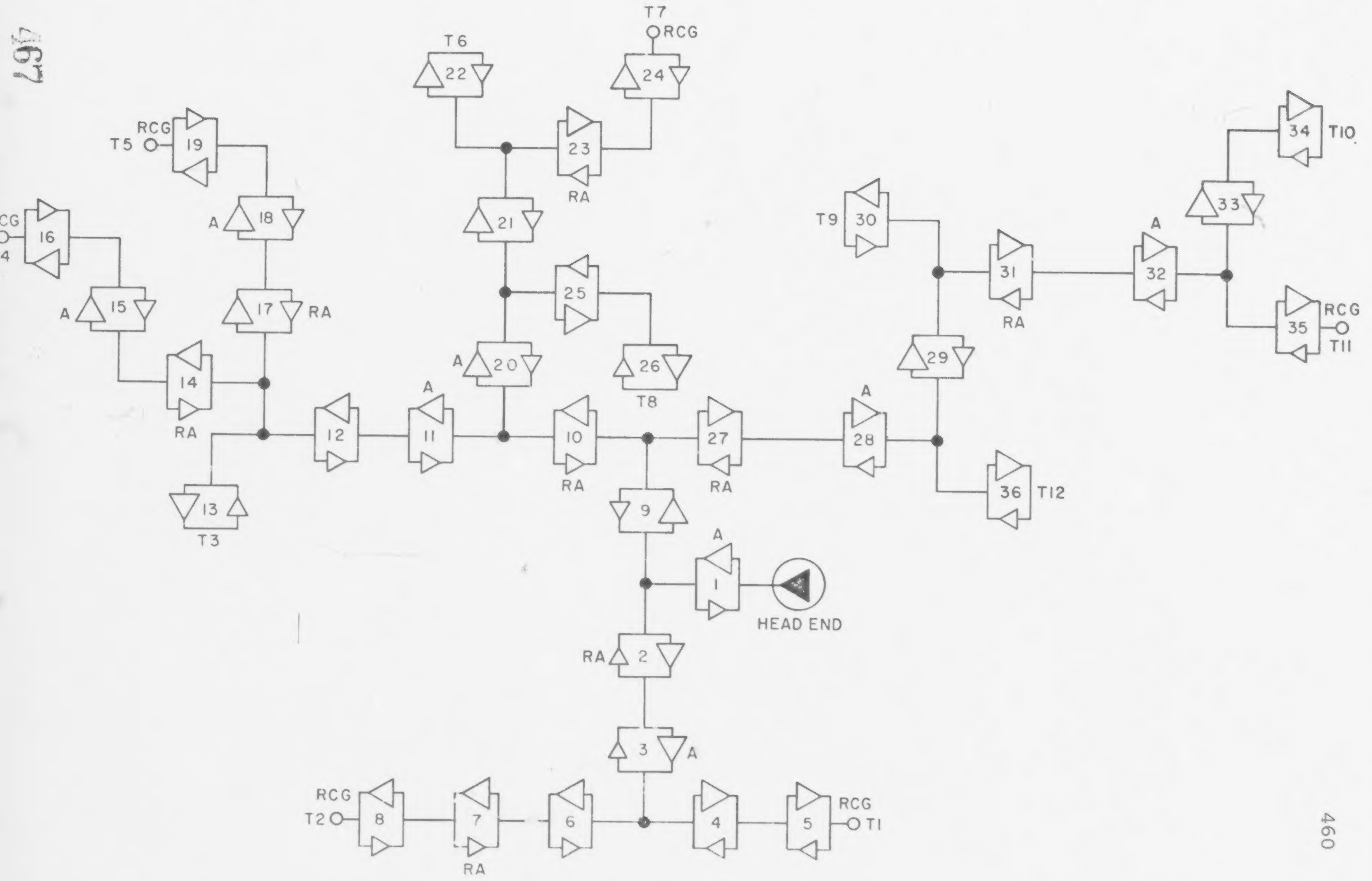
It would be feasible to precisely control the frequency of the return pilot by originating a single carrier at the head end and sending it through the system to the branch terminations where it would be received and counted down in frequency. A sub harmonic of the source signal could then be used as the pilot carrier for the return system.

A major problem with this scheme is the phase relationship between two return pilot carriers at a branch junction. Since the round trip distance from a branch split to the branch terminations and back to the branch junction will not necessarily be the same for both branches, the two return pilot carriers will appear at a branch junction with a phase relationship which is dependent upon the difference in length between the two branches.

For example, on the trunking diagram in figure 1, the reference carrier passing through Amp #2 in the forward direction would be split just beyond Amp #3 and continue on to the branch terminations T1 and T2 where it would be counted down and returned to the branch junction just before Amp #3. At the branch junction the two pilot carriers would be combined and continue on to the return AGC amplifier at Amp #2. The round trip difference in path length of the two signals would be two spans, or approximately 4,000 feet. Assuming a sub split system with 90 Mhz outgoing for the reference carrier and 30 Mhz for the return pilot carrier, there would be a difference of 223.46 wave lengths out and 74.49 on the return for a total difference of 297.95 wave lengths, which would put the two return pilot carriers 18° out of phase. (See Addendum I)

This in itself is not too important. What is critical, however, is the change in phase relationship with temperature. A complete 180° phase shift between the two return pilot carriers would occur with a change in round trip electrical length of only 6.71 feet (see Addendum I). Assuming that the electrical length of cable changes approximately .1%/°F or 1 ft./°F per 1,000 feet, a temperature change of 1.67°F would cause a complete 180° shift in the phase relationship between the two return pilot carriers. The two return pilot carriers would swing between in phase voltage addition and complete cancellation with the slightest

TWO WAY SYSTEM TRUNKING DIAGRAM


T7
RCG
T6
22
24
RCG
T5
19
23
RA
34
T10
CG
4
16
A
18
21
T9
30
A
33
A
15
17
RA
25
31
32
RA
35
RCG
T11
A
20
26
T8
29
14
RA
A
12
11
10
RA
27
RA
A
28
36
T12
13
T3
9
A
1
HEAD END
RA
2
3
A
RCG
T2
8
7
RA
6
4
5
RCG
T1

change in temperature. This signal variation would also appear to the AGC circuitry as a double side band AM modulated wave. Since the frequency of modulation would be typically much less than one cycle per minute, it could not be filtered out by any practical AGC circuitry and the return system levels would hunt continuously.

Assuming a mid split system with 242 Mhz outgoing for the reference carrier and 121 Mhz for the return pilot carrier, there would be a difference of 601.01 wave lengths out and 300.51 wave lengths on the return for a total difference of 900.51 wave lengths which would put the two return pilot carriers 184° out of phase. (See Addendum 1) The phase shift vs. temperature for the mid split system is even more radical than for the sub split system. A complete 180° phase shift between the two return pilot carriers would occur with a change in round trip electrical length of only 2.22 feet (see Addendum I). Assuming that the electrical length of cable changes approximately 1 ft./°F per 1,000 feet, a temperature change of .55°F would cause a complete 180° shift in the phase relationship between the two return pilot carriers.

III. Modulated Pilot Carrier

The use of a return pilot carrier with a single modulating frequency would incur essentially the same problems as would be incurred with use of a CW return pilot carrier. These problems could be circumvented by using a different crystal controlled modulating frequency in the range of 1 Khz to 10 Khz for every return carrier generator in the system. The return AGC amplifiers could then be designed with a very sharply tuned audio filter to respond only to the appropriate return pilot carrier, ignoring all others. This would entail the use of matched return carrier generators and AGC amplifiers which would in turn cause a tremendous stocking problem and allow for no interchangeability of return carrier generators or AGC amplifiers.

In order to prevent amplifier overload due to an increase in the number of return pilot carrier signals on the system as you approached the head end, it would be necessary to utilize some pilot carrier trapping at various locations in the system.

Use of a modulated pilot carrier in the forward direction only, however, does have some advantages over use of a CW pilot carrier in that it simplifies the AGC circuitry and the problems involved in the temperature stabilization of a DC amplifier.

It does, however, present the possibility of modulation transfer. This is the phenomenon of the transfer of the modulation of the pilot carrier through the action of the AGC to every channel passing through the amplifier controlled by the AGC. The time constant or filtering action of the AGC should be capable of rejecting the pilot carrier modulation so that the transferred modulation is down at least -90db or by an amount equivalent to the crossmod specification of the amplifier for full channel loading at operational output levels.

To fully appreciate the modulation transfer caused by amplifier gain variations which occur at the modulating frequency rate, consider that a gain change of 0.05% is equivalent to -60db crossmod. (See Addendum II) It should be noted that AGC amplifiers which were designed to operate strictly from a CW pilot carrier should be checked very carefully for modulation transfer before they are used in a system with a modulated pilot carrier. It is most likely that they will be found to be unsatisfactory.

Use of a live video signal for a return pilot carrier may be considered, however there is no guarantee of the presence of a live video signal in the branch to be controlled at any particular time. It would be necessary, therefore, to employ one of the types of return carrier generators previously discussed for use as a standby carrier generator.

The three types of return pilot carrier systems which we have just discussed all have some serious drawbacks which make their use difficult or impractical, if not impossible. Another type of signal, however, which appears to have excellent potential as a return pilot carrier is a white noise signal.

IV. Narrow Band Noise Spectrum as a Pilot Carrier

Consider the use of a 1 Mhz wide white noise spectrum as pilot carrier for the return AGC system. White noise may be defined as a random process with constant spectral density. The random signal distribution and phase relationship of this type of signal will prevent the modulation and phasing problems encountered with the mixing of two or more coherent signal sources as in the previous cases.

In order to keep the return pilot carrier level from building up everytime two AGC controlled branches are combined it will be necessary to trap out one half of the return pilot carrier whenever combination occurs. This could be accomplished by trapping out one of the pilot carriers by 16db or more, as opposed to 39db or more for the combination of two coherent, signals and allowing the other to continue unimpeded. A more reasonable approach would be to allow the two pilot carriers to combine at a branch junction and then trap the resultant signal by 3db.

One advantage of this method is that now, no one return pilot carrier is originating from a primary or controlling source. Since each pilot carrier source is contributing only a fractional part to the total pilot carrier energy, failure of any one pilot carrier source will not cause a complete disruption of system levels. For example, refer to the trunking diagram in figure 1. Note that there are a total of six return pilot carrier sources, one located at each of the following branch terminations: T1, T2, T4, T5, T7 and T11. If any one of these sources failed, the change in level at Amp #1 due to this failure would be $10 \log_{10} 1-\frac{1}{2^N}$ where N is the number of times the pilot carrier is combined with pilot carriers from other branches.

Let us examine in detail the resultant level changes which would occur with complete failure of one or more of tne return system pilot carriers. Whenever a pilot carrier is combined and trapped down 3db there will be remaining 1/2 of its original signal energy. Every time two return pilot carriers are combined, the remaining energy will be one half the sum of the two pilot carriers before combination. If a pilot carrier from a specific return carrier generator is combined and trapped 3 times, its remaining energy level will be $1/2^N$ or 1/8 of its original energy level.

If, for example, Amp #10 were receiving pilot carrier energy from return carrier generators hypothetically located at branch terminations T3, T4, T5, T6, T7 and T8, the fractional part of the total signal contributed by each return carrier generator would be 1/4, 1/8, 1/8, 1/8, 1/8 and 1/4, respectively.

Since the system shown on the trunking diagram is small (13.5 miles of trunk) and has only 12 terminations, let us simulate a larger system by assuming that there is a return carrier generator located at each one of these terminations. If the return carrier generator located at termination T5 were to fail completely, the return AGC module at Amp #17 would go to full gain since there would be no return pilot carrier whatsoever at that AGC location. At Amp #10, the next return AGC in the path between termination T5 and the head end, there would normally be return pilot carrier signals from 6 different terminations, T3, T4, T5, T6, T7 and T8, each contributing a fractional part equal to $1/2^N$ of the total return pilot carrier energy. Failure of the return carrier generator at T5 would leave $1-\frac{1}{2^3}$ or 7/8 of the original signal level remaining for a change of only 0.58db. Failure of the return carrier generators at both T4 and T5 would cause a change of 1.23db in the level of the return pilot carriers at Amp #10. Failure of the return carrier generators at T4, T5 and T8 would leave $1-(\frac{1}{2^3}+\frac{1}{2^3}+\frac{1}{2^2})$ or 1/2 of the original signal level remaining, resulting in a 3db change in the return pilot carrier level at Amp #10.

In a section of a large system with over 200 strand miles of CATV plant, there could be well over 100 branch terminations requiring up to 50 return carrier generators. Under these conditions, failure of any one or even a few return carrier generators would have a small effect on the total system performance.

Another advantage of combining the return pilot carriers and then trapping them down 3db is that the resultant pilot carrier will then be more representative of the signal variations caused by thermal changes in the individual branches. In other words, it would tend to have an averaging effect for thermal changes in branches of different lengths. This would tend to keep the system operating in a reserve tolerance range that would be equally distributed between crossmod and noise.

Note for example, on the trunking diagram that the return pilot carriers originating at terminations T1 and T2 will both have an equal effect on the return AGC module located at Amp #2. The level correction applied at Amp #2 will be an average of the level changes occurring in the two branches which are joined just before Amp #3.

Again, refer to the trunking diagram in figure 1. This diagram represents the trunking layout for a small 45 mile system with approximately 13.5 miles of trunk and a total of 36 trunk stations including terminating bridging amplifiers. The system uses eight AGC's in the forward direction, eight AGC's in the return direction, one forward pilot carrier and six return pilot carriers.

The locations of the AGC amplifiers in the forward direction were chosen on the following conditions:

1. AGC every third station.
2. An AGC which would normally fall one location beyond a trunk split is backed up and located before the split.
3. An AGC is located no more than two spans from a terminating bridging amplifier.

Since these rules are mutually exclusive in many cases, compromise must be made by applying weighting factors to the above rules or by using judgment based on the desired results.

In the return direction, the situation is somewhat more complex in that the return signals may be arriving at a return AGC via two or more paths of different length. For example, Amp #21 is receiving signals from T6 and T7 while Amp #10 is receiving signals from T3, T4, T5, T6, T7 and T8. Even in a common path, a return AGC may be receiving signals over varying lengths of cable. Amp #17, for example, is receiving return signals from Amps #19, #18 and #17, each a different length path requiring a different thermal compensation at Amp #17.

Unlike in the forward direction where this type of signal level error will affect only those stations or subscribers between which level correction is applied, any level errors in the return direction produced by thermal changes or equalization errors will be carried back through the entire system to the head end where it will appear as a level error, consequently picking up additional crossmod and noise at every return station along the way. Level errors in the return direction caused by thermal changes or improper equalization are therefore potentially much more serious than the same type errors in the forward direction. In fact, they are equivalent to head end level errors in the forward direction.

The locations of return AGC amplifiers were chosen on the following conditions:

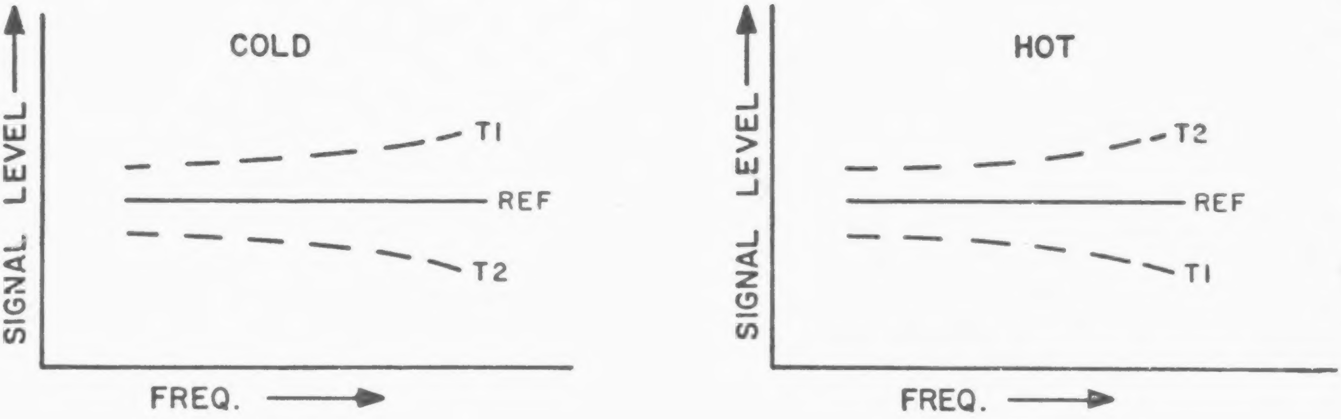
1. AGC every third station.
2. A return AGC is located, where possible, so that it is the same number of spans from all other control or originating points. For example, return AGC Amp #10 is receiving signals from AGC Amps #14, #17 and #23, and terminating bridging Amps #13 and #26. Note that all five paths are three spans in length. Return AGC Amp #2 is receiving signals from AGC Amp #7 and terminating bridging Amp #5. Again note that all paths are three spans in length.

This tends to establish a fixed relationship between the levels of the return signals entering the system from the various branch terminations and the levels of the return pilot carriers on the system.

Consider the case where return signals are entering the system at every amplifier location. Under these conditions it is impossible to have a fixed relationship between every one of the return signals and the return pilot carrier. The optimum condition would be achieved if the variations of the return pilot carrier level were an average of the variations of all the return signals. It is not necessary to locate a return pilot carrier generator at every branch termination. The level variations of the return pilot carrier can be made to represent the average of all the return signal level variations by judiciously locating the return carrier generator so that its distance from a common return AGC is an average of the distance of all the signals entering the system.

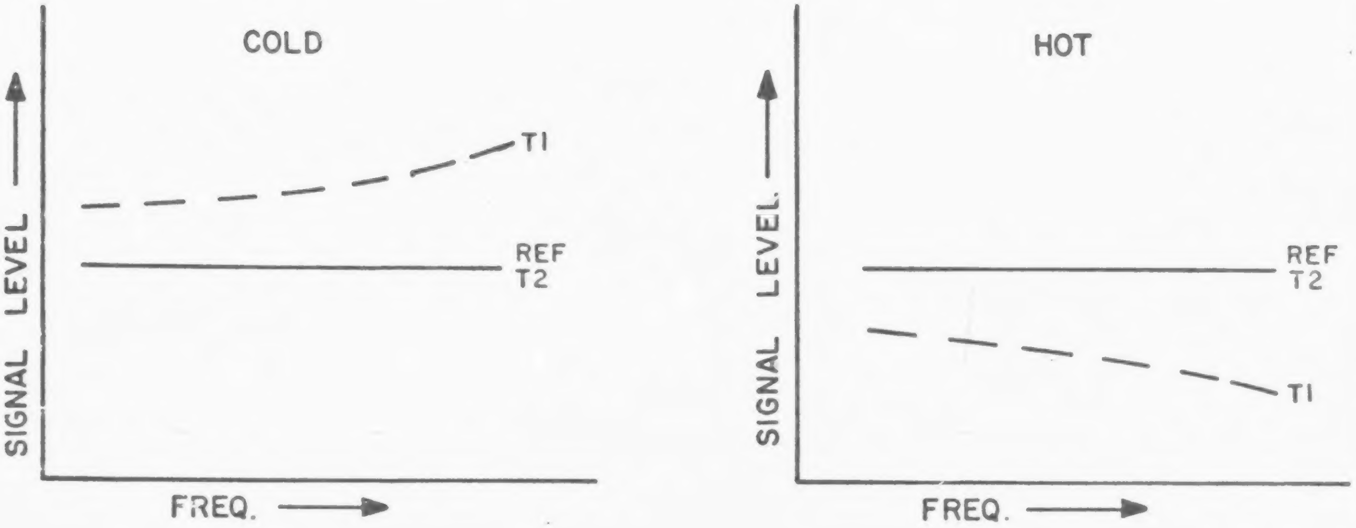
On the trunking diagram, figure 1, note that the return AGC module located at Amp #31 is controlled by a return pilot carrier source at branch termination T11. The return amplifier module at Amp #31 is receiving signals from Amps #31, #32, #33, #34 and #35. Note that the corresponding span lengths to Amp #31 are, allowing 1/2 a span for the feeder run, 1/2, 1 1/2, 2 1/2, 3 1/2 and 2 1/2 spans respectively with the average span length being 10.5/5 or 2.1 spans. The return AGC module located at Amp #31 will, therefore, tend to over compensate for level variations on signals originating at Amps #31 and #32, and under compensate for level variations on signals originating at Amp #34 while properly compensating for level variations on signals originating at Amps #33 and #35, therefore averaging out the signal level errors.

To appreciate the effect of level averaging achieved by trapping down return pilot carriers by 3db when they are combined and by the judicious selection of locations for return carrier generators, refer to figures 2 and 3.



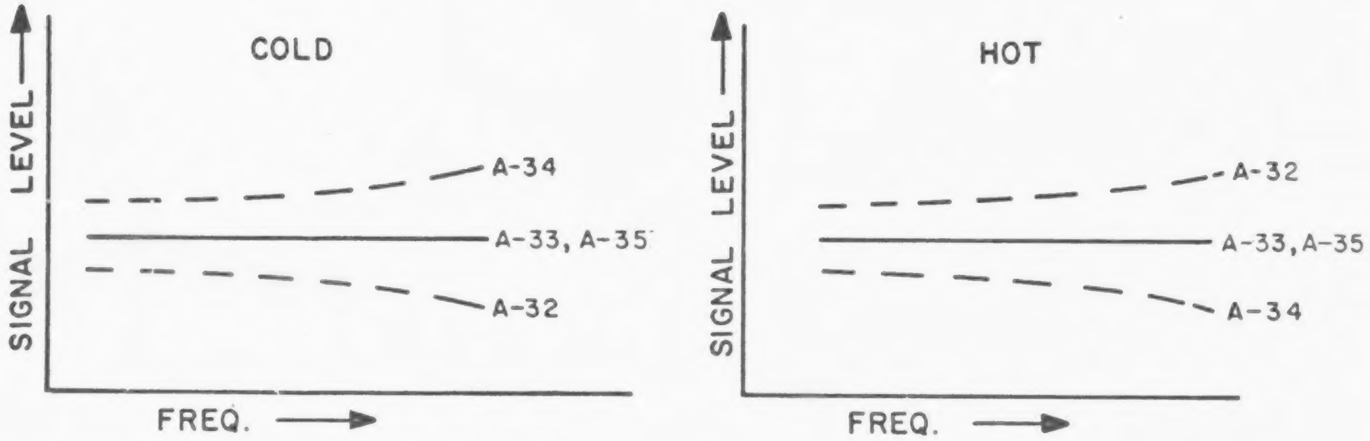
SIGNAL LEVEL VARIATION VS. TEMPERATURE
RETURN PILOT CARRIER AT T1 & T2 TRAPPED DOWN -3dB

FIG. 2A



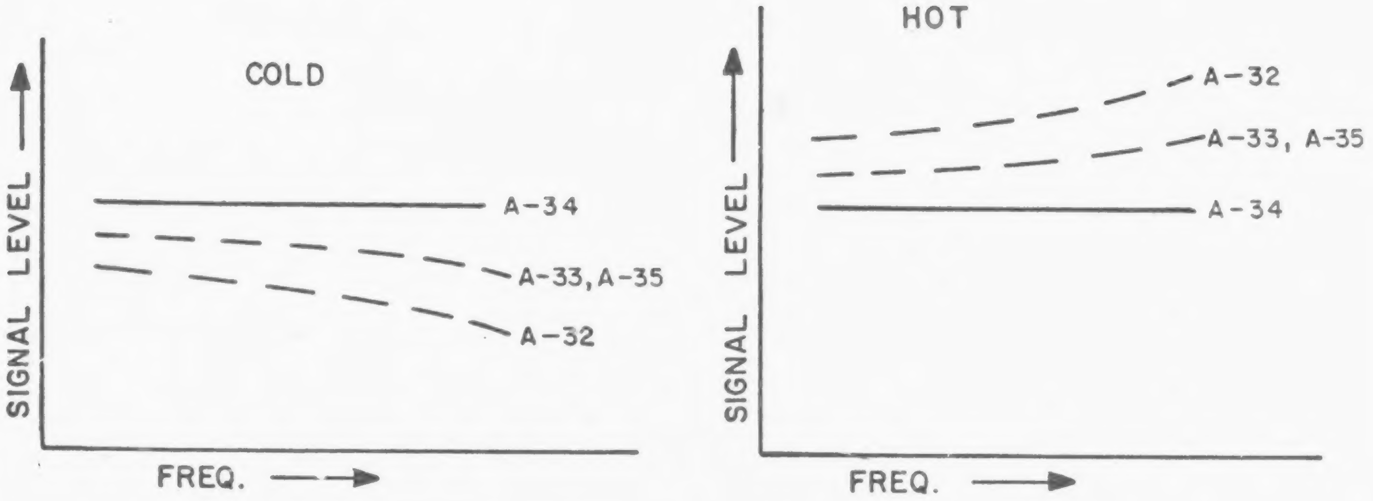
SIGNAL LEVEL VARIATION VS. TEMPERATURE
RETURN PILOT CARRIER AT T2 ONLY

FIG. 2B



SIGNAL LEVEL VARIATION VS. TEMPERATURE
RETURN CARRIER GENERATOR LOCATED FOR LEVEL AVERAGING

FIG. 3A



SIGNAL LEVEL VARIATION VS. TEMPERATURE
RETURN CARRIER GENERATOR IMPROPERLY LOCATED

FIG. 3B

Figure 2A shows the level averaging effect achieved at Amp #2 between signals originating at branch terminations T1 and T2 when the return pilot carrier is trapped down 3db and the resultant pilot carrier level is 1/2 the sum of the two original pilot carrier levels. Figure 2B shows the effect of using a single return carrier generator at branch termination T2 only. Note that in figure 2A where signal averaging is utilized the maximum signal level variation is about half that in figure 2B where a single return pilot carrier controls the levels originating at both terminations.

Figure 3A shows the effect of level averaging achieved by selecting the location of the return carrier generator so that its distance from the return AGC is an approximate average of all the other signals entering the system and passing through the same AGC. Figure 3B shows the effect of improperly locating the return carrier generator at branch termination T10. Note that in figure 3A where signal averaging is utilized the maximum signal level variation is again about half that in figure 3B where the return carrier generator is improperly located.

In both cases where signal averaging is utilized, the maximum signal level variation is less, thereby increasing the reserve tolerance margin that can be allocated to other parts of the system. As mentioned before, it is very important to keep signal level variations in the individual branches to a minimum since these level variations will be carried through the entire system back to the head end.

In a system where AGC or thermal level control is applied only at every third amplifier location, the input and output levels at the stations in between will vary with temperature. These level variations which are caused primarily by cable loss and amplifier gain variations with temperature raise or lower the station input levels from their nominal design center. This increases the distortion or noise picked up at these stations, thereby reducing the overall system tolerance reserve.

To reduce signal level and system distortion and noise variations with temperature, AGC or some other type of thermal level control should be applied at every station in both the forward and reverse directions. This is especially true for signals traveling in the reverse direction since, as noted before, these level errors will be carried through the entire system back to the head end. If the manual stations in the system are designed to compensate for thermal changes in an average cable span (open loop AGC) the differences in level variations between signals originating at various distances from a return AGC amplifier will then be held to a minimum.

We have discussed the advantages and disadvantages of various types of AGC pilot carriers for use in the return portion of a two-way system and have attempted to point out some of the potential problems which may be incurred by the use of CW or modulated signals of the type normally used as pilot carriers in the forward direction. We have introduced the concept of a narrow band noise spectrum which, because of its random signal distribution and phase characteristics, is an ideal pilot carrier for the return system.

We have chosen a typical small system and have shown how improved signal level control can be achieved by judiciously selecting the locations of the return carrier generators and AGC amplifiers so that the return pilot carrier level variation is representative of the average level variation of all the return signals at a common point.

We have shown further how the differences in return signal level variation can be held to a minimum by the use of both closed loop and open loop AGC's and how, by holding these level variations to a minimum, we can achieve improved system performance.

ADDENDUM I

Phase difference for different path lengths - Sub-Split Systems

f out = 90 Mhz   f return = 30 Mhz

$$L1 = V/f = \frac{186{,}000 \text{ mi/sec} * 5280 \text{ ft/mi} * .82}{90 * 10^6 \text{ hz}}$$

L1 = 8.95 ft.

L2 = 3 * L1 = 26.85 ft.

Assume 1 way difference in distance between Termination #1 (T1) and Termination #2 (T2) is 2000 ft.

$$@\ 90 \text{ Mhz} \quad \frac{2000 \text{ ft.}}{8.95 \text{ ft/cyc}} = 223.46 \text{ cycles}$$

$$@\ 30 \text{ Mhz} \quad \frac{2000 \text{ ft.}}{26.25 \text{ ft/cyc}} = \underline{74.49 \text{ cycles}}$$

$$297.95 \text{ cycles} = 297 \text{ cyc} + 342^{\circ}$$

Phase Shift vs. Temperature for different path lengths

Change in cable electrical length = .1%/$^{\circ}$F

.001 * 1000 ft. = 1 ft./$^{\circ}$F

360° phase shift = 3/4 L1 + 1/4 L2 = 6.71 ft. out & 6.71 ft. return

180° phase shift = 6.71/2 = 3.355 ft.

$$\text{Temperature change for } 180^{\circ} \text{ phase shift} = \frac{3.555 \text{ ft.}}{2.0\text{K ft.}} = 1.67^{\circ}\text{F}$$

Phase difference for different path lengths - Mid-Split System

f out = 242 Mhz   f return = 121 Mhz

$$L1 = V/f = \frac{186{,}000 \text{ mi/sec} * 5280 \text{ ft/mi} * .82}{242 * 10^6 \text{ hz}}$$

L1 = 3.33 ft.

L2 = 2 * L1 = 6.66 ft.

Assuming 1 way difference in distance between Termination #1 (T1) and Termination #2 (T2) is 2000 ft.

@ 242 Mhz $\frac{2000 \text{ ft.}}{3.33 \text{ ft./cyc}}$ = 601.01 cycles

@ 121 Mhz $\frac{2000 \text{ ft.}}{6.66 \text{ ft./cyc}}$ = 300.51 cycles

900.51 cycles = 900 cyc + 184°

Phase Shift vs. Temperature for different path lengths

Change in cable electrical length = .1%/$^{\circ}$F

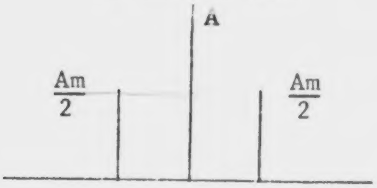
360° phase shift = 2/3 L1 + 1/3 L2 = 2 22 ft. out & 2.22 ft. return

180° phase shift = 2.22/2 = 1.11 ft.

Temperature change for 180° phase shift = $\frac{1.11 \text{ ft.}}{2.0\text{K ft.}}$ = .55°F

ADDENDUM II

Transferred Modulation (TM) as a function of amplifier gain variation (m).



For 100% modulation:

Relative level of carrier A = .5

Relative level of each sideland $Am/_2 = .25$

$$A\ (1 + m) = 1$$

(1) $A = \frac{1}{1 + m}$

also $A + Am = 1$

(2) $Am = 1 - A$

substituting (1) above:

(3) $Am = 1 - \frac{1}{1 + m}$

Referencing (3) to the sideband energy level of a 100% modulated signal, we find that the transferred modulation, TM, is:

$$TM = \frac{1 - \frac{1}{1 + m}}{1/2}$$

which reduces to:

(4) $TM = \frac{2m}{1 + m}$

expressed in db:

(5) $TMdb = 20 \log_{10} \frac{2m}{1 + m}$

%m % Gain Variation	TMdb Transferred Modulation in db
100.0	0.
50.0	- 3.52
25.0	- 7.96
10.0	- 14.81
5.0	- 20.42
2.5	- 26.24
1.00	- 34.07
0.50	- 40.04
0.25	- 46.04
0.100	- 53.99
0.050	- 60.00
0.025	- 66.02
0.0100	- 73.98
0.0050	- 80.00
0.0025	- 86.02
0.00100	- 93.98
0.00050	-100.00
0.00025	-106.02

CONTRIBUTING SOURCES AND MAGNITUDES OF ENVELOPE DELAY IN CABLE TRANSMISSION SYSTEM COMPONENTS

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INTRODUCTION

Two-way transmission on a single cable system has focused attention on the cable system performance parameter group delay distortion (or variation), which previously was only of major concern in single channel head end equipment and off air signals. Group delay distortion is not the only important parameter which must be considered, but it is the topic of this paper. This paper covers the following topics:

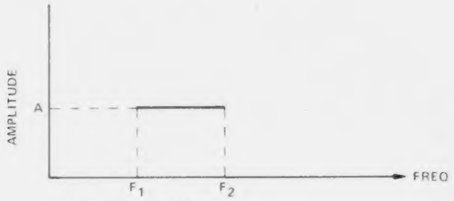
1. Sources of group delay distortion in the single cable, 2-way cable system.
2. Examples of calculated and measured group delay of cable system components.
3. Methods of minimizing group delay distortion in the cable system.

It is well known that frequency division multiplex (FDM) filters are the primary cause of group delay distortion in a single cable, 2-way transmission system. The group delay characteristics of other cable system components were also investigated, however, since very little information has been published for these components. Permissable magnitudes of group delay distortion based on test results of subjective viewing are discussed in detail in Reference 1, and will only be mentioned in this paper.

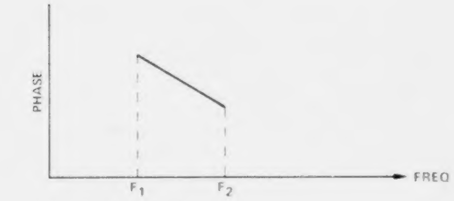
Techniques for correcting or equalizing transmission path delay distortion which is considered unacceptable are discussed. The application of delay equalizing methods will require new products from CATV equipment manufacturers and the use of special test equipment by the system operator.

REVIEW OF IDEAL LINEAR SYSTEM CHARACTERISTICS

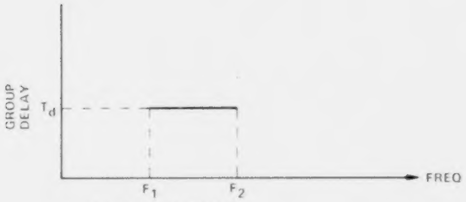
Signal information transmitted through a transmission system or device contains a finite band of frequencies. If the system or device has a flat amplitude response and a linear phase response over the band of signal frequencies, the output is an exact replica of the input, delayed in time, and directly proportional in amplitude to the constant gain factor A (See Figure 1, 2)



(a) AMPLITUDE RESPONSE



(b) PHASE RESPONSE



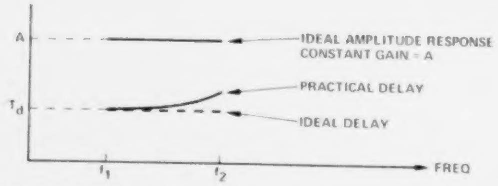
(c) GROUP DELAY RESPONSE

FIGURE 1 IDEAL SYSTEM OF BANDWIDTH (F_2-F_1) AMPLITUDE, PHASE, AND DELAY RESPONSE

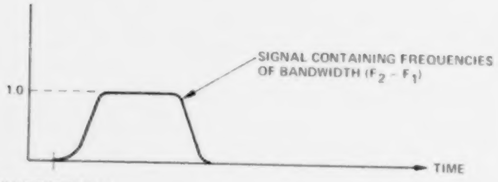
Any device or component containing energy storage elements such as inductors and capacitors will produce phase shifts. Phase shift versus frequency is linear in the ideal system. Envelope delay (synonymous with group delay) is defined as the rate of change of phase shift with respect to frequency. Another way of saying this is that envelope delay is the incremental slope of the phase shift versus frequency curve of the transmission system. Linear phase means constant delay, as shown in Figure 1C.

The envelope delay response of cascaded systems or components is additive, just as is the decibel amplitude response of cascaded systems or components. Therefore, knowing the envelope delay of each individual piece of equipment in a cascade, the envelope delay of the total cascade can be determined by simple arithmetic addition. For example, a cascade of ten identical filters, each filter having an envelope delay of 3 nanoseconds, has an envelope delay of 30 nanoseconds. This principle is also helpful for designing delay equalizers.

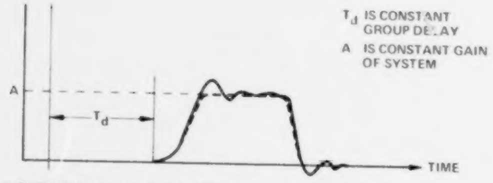
In the non-ideal or practical situation, equipment will introduce amplitude distortion (response not perfectly flat over frequency band) and group delay distortion (response not constant at each signal frequency). An example of the effect of the delay response of practical hardware is shown in Figure 2C. In addition to waveform distortion caused by delay distortion, misregistration of chroma information in the television color signal will also result. Note that the output of an ideal system is a replica of this input signal, delayed in time, and modified by the constant gain factor A.



(a) SYSTEM RESPONSE



(b) INPUT SIGNAL



(c) OUTPUT OF SYSTEM WITH GROUP DELAY DISTORTION
DASHED WAVEFORM IS OUTPUT OF IDEAL SYSTEM

FIGURE 2 EXAMPLE OF SIGNAL TRANSMISSION THRU SYSTEM WHICH HAS IDEAL AMPLITUDE RESPONSE AND NON-IDEAL DELAY RESPONSE

TYPES OF DELAY DISTORTION

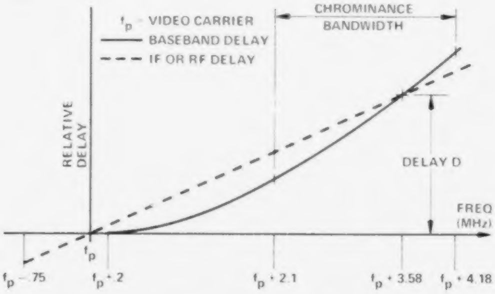
The NTSC color television signal consists of luminance and chrominance information. The delay difference between the chrominance and luminance signal will cause misregistration of color information, and, in addition will effect the transient response of the television signal. Chroma delay is defined as the difference between the chrominance and luminance carrier. Two types of delay distortion which are present in the transmission path between televised scene and subscriber television set picture are flat delay and shaped delay.

Flat delay difference may occur when the luminance and chrominance signal are processed separately at video frequencies, introducing a constant delay between the two signals. The broadcast studio and home receiver would be the most common source of this type of distortion. Flat delay distortion will not be considered in this paper.

Shaped delay applies to the video signal after luminance and chrominance signals are combined. Shaped delay is a change of delay at each frequency across the video or signal bandwidth.

In the tests described in Reference 1, a shaped delay error of 178 nanoseconds was considered the mean value of delay error for which the subjective effect was rated as just perceptile. A shaped delay distortion error of 477ns was the mean value for a subjective effect rated as "impairment to picture, but not objectionable".

The magnitude of shaped delay distortion is commonly taken to be the difference in delay between the 3.58 MHz and 0 to 200 KHz regions of the video channel Two shaped delay characteristics are shown graphically in Figure 3.



SHAPED DELAY DIFFERENCE VERSUS FREQUENCY
D IS DELAY DIFFERENCE BETWEEN 3.58 MHz AND
0 200 KHz REGION OF VIDEO CHANNEL

FIGURE 3

The dashed curve is representative of the type of delay distortion present in FDM filters and other broadband cable system components. The slope of the shaped delay curve can be either positive or negative, depending on the particular component properties. The solid curve is typical of those shown in the literature referring to baseband video, and, therefore, the delay characteristic does not extend below a carrier frequency. Articles, such as Reference 4, concerned with the design of narrowband RF and IF amplifiers, do address this problem of delay below a carrier.

ENVELOPE DELAY OR CABLE SYSTEM COMPONENTS

In the CATV Industry there was very little concern for envelope delay in cable system components until the study and development of two-way transmission on a single delay cable began a few years ago. The major sources of group delay were either already present in the signal received by the cable system, generated in the CATV head-end equipment, generated in the subscriber television receiver, or some combination of all three. Since most cable system components had gradually changing amplitude responses, which usually indicated gradually changing phase response, very little group delay distortion was generated. Also, the channel bandwidth, and even more specifically, the 3.58 MHz frequency difference between chrominance and luminance carriers in a single channel is a small percentage bandwidth compared to the broadband response of these components. In this paper, components are defined as functional units or pieces of equipment such as cable, equalizer, filter, amplifiers, splitters, directional taps, etc.

Frequency division multiplex (FDM) for 2-way transmission of signals on a single cable requires that the frequency spectrum be split, one portion used for forward (downstream) transmission and one portion used for reverse (upstream) transmission. The transmission band split is accomplished by the use of high pass and low pass filters and has been discussed in detail in a number of articles (References 6, 7, 8). A block diagram of a two-way transmission repeater amplifier is shown in Figure 4. The FDM filters must be located at each amplifier and must have relatively sharp cutoff characteristics (compared to other cable system components). Group delay distortion is proportional to rate of attenuation change versus frequency. In other words, the more rapidly the amplitude response changes with frequency, the more group delay distortion is present. The major contribution to cable system group delay distortion is due to FDM filters. The low end of the sub channel band (such as CH T-7, 5.75 to 11.75 MHz) delay distortion is due to sources other than FDM filters. To fully characteristize the system delay, each component in the transmission path should be evaluated.

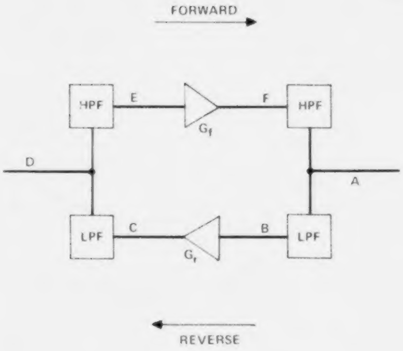


FIGURE 4 BLOCK DIAGRAM OF TWO-WAY REPEATER AMPLIFIER

The single cable system used for two-way transmission is actually split into two bandpasses and there are four cutoff frequencies as shown graphically in Figure 5. For the two bands shown in Figure 5, the FDM filters cause a sharp rate of attenuation beginning below 54 MHz for the downstream bandpass and above 30 MHz for the upstream bandpass.

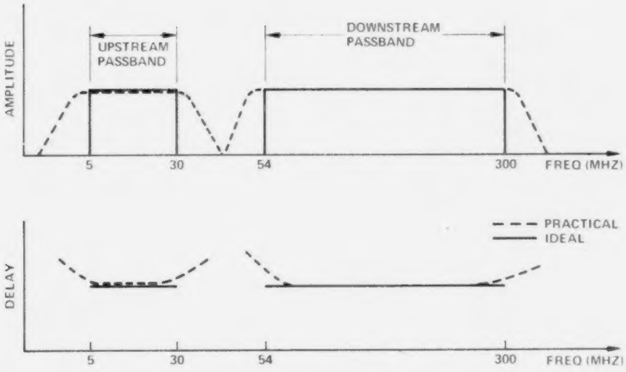


FIGURE 5 SKETCH OF IDEAL AND PRACTICAL AMPLITUDE AND DELAY RESPONSE OF SINGLE CABLE TWO-WAY TRANSMISSION SYSTEM

DOWNSTREAM PATH

The response above 300 MHz (or the highest frequency) in the downstream path will attenuate gradually due to amplifier gain roll-off and cable attenuation equalizer roll-off. Because of this fact and the fact that the ratio of 3.58 MHz/300 MHz is approximately one-sixth the value of the ratio of 3.58 MHz/55 MHz, delay distortion at the high end of the downstream across a 3.58 MHz will be very low. Therefore, the emphasis on delay distortion minimization in the downstream path is at the low end of the band and predominately attributable to FDM filters.

UPSTREAM PATH

The delay distortion problem in the upstream passband is accentuated because a 3.58 MHz bandwidth is a much higher percentage bandwidth ($\frac{3.58}{8.75} = .41$ for channel T7, and $\frac{3.58}{26.75} = .134$ for channel T10). Delay distortion at the high end of the upstream band will be caused mainly by the FDM filter design. However, the upstream cable attenuation equalizers also contribute delay distortion. The low end response of the upstream band is similar to that of a high pass filter. The high pass filter type response results from both the power frequency blocking capacitors and passing chokes plus response roll-off due to the magnetics used in line splitters and directional couplers.

GROUP DELAY OF LOW-LOSS CABLE

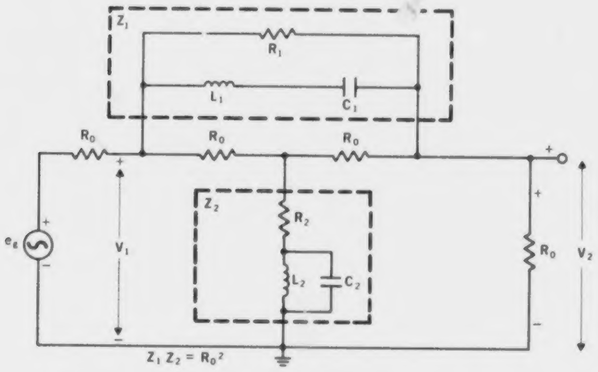
The equations used for the calculation of low-loss cable group delay are listed in Appendix I. The results of these calculations for two types of cable are summarized below. The chroma delay (delay of chroma carrier minus delay of channel carrier) is so small that it is negligible, as expected.

TABLE 1

		CHROMA DELAY NSEC/10,000 FEET	
CHANNEL	FREQ (MHZ)	500 CABLE	750 CABLE
T7	10.58	-.0297	-.0137
2	58.83	-.00071	-.00033

GROUP DELAY OF BRIDGED-T EQUALIZER

A cable attenuation equalizer is a form of band pass filter. The attenuation slope of this band pass filter is used to equalize the cable attenuation. A type of cable equalizer which is common in many CATV amplifiers is referred to as a constant resistance bridged-T equalizer. A schematic of such an equalizer is shown in Figure 6.



BRIDGED-T, CONSTANT RESISTANCE EQUALIZER CIRCUIT SCHEMATIC

FIGURE 6

Assuming a constant source and load impedance of Ro (Ro = 75 ohms for CATV applications) the expression for its insertion loss is:

$$\frac{V_1}{V_2} = 1 + Z_{1/Ro} \qquad (1)$$

The term Z_1 is a function of frequency and is a complex number, so it therefore contains a real and imaginary term. The expression for the equalizer phase shift is

$$\text{Phase}\left(\frac{V_2}{V_1}\right) = \text{P= Arctan} \left(\frac{\text{imaginary part of } Z_{1/Ro}}{1 + \text{real part of } Z_{1/Ro}}\right) \qquad (2)$$

The expression for phase shift is needed to calculate the group delay which is

$$\text{Group Delay}\left(\frac{V_2}{V_1}\right) = D = \frac{-dp}{dw} \qquad (3)$$

where $w = 2\pi f$

Expression (3) was evaluated for an equalizer similar to that shown in Figure 6. An equalizer response for the 5-30 MHz frequency band and the 50 to 300 MHz band was calculated and also breadboarded. The cable loss plus equalizer loss was flat within 1.0 dB peak to valley over the passband. Delay values were measured using a General Radio Type 1710 Analyzer system. The delay magnitude of the 50-300 MHz equalizer was calculated at less than 2 ns across the band, so that a meaningful measurement could not be obtained. However, the delay magnitude measured on the 5-30 MHz equalizer was within the resolution of the test equipment and agreed well with the calculated values.

Calculated delay values for the two equalizers are summarized in Table 2. The equalizers were designed based on the Anaconda SLM 750 cable attenuation characteristic. The dB value of equalizer shown refers to the dB loss of cable at either 30 MHz or 300 MHz.

TABLE 2

5-30 MHZ 6 dB EQUALIZER				50-300 MHZ 17 dB EQUALIZER			
FREQ. (MHZ)	CABLE + EQU. LOSS (dB)	PHASE (DEG)	DELAY (NSEC.)	FREQ. (MHZ)	CABLE + EQU. LOSS (dB)	PHASE (DEG)	DELAY (NSEC.)
7.0	-6.2	4.8	-1.78	55.25	-10.8	17.3	-.24
10.58	-6.7	7.0	-1.58	58.83	-10.8	17.6	-.21
19	-6.9	10.7	- .70	211.25	-10.9	19.4	+.28
22.58	-6.6	10.9	+ .68	214.83	-10.9	19.0	+.31
25	-6.3	9.5	+2.67	295.25	-10.9	1.33	+.78
28.58	-5.9	3.5	+6.51	298.83	-11	.33	+.78

Group Delay of Downstream Flat Gain Repeater Amplifier

The group delay variation versus frequency of flat gain broadband hybrid integrated circuit amplifiers (for use over 50-300 MHz band) now in production is very low. One reason for this is that the amplitude response of these IC amplifiers (two types manufactured by Hewlett Packard) is flat from approximately 20 MHz to greater than 330 MHz. The response roll-off at the band edges is also gradual, so that very little group delay variation occurs in a passband of 54 to 300 MHz. In addition, it is possible to reduce the effect of circuit parasitics, so that the appropriate element values can be used.

Using the same principle of extending the bandwidth beyond the passband frequencies, the upstream amplifiers will also have low values of chroma delay in the passband. Care must be taken to insure that the low frequency cutoff extends well below the lowest frequency of 5 MHz and yet rejects the power frequency of 60 Hz.

Channel T-7 and T-8 Chroma Delay

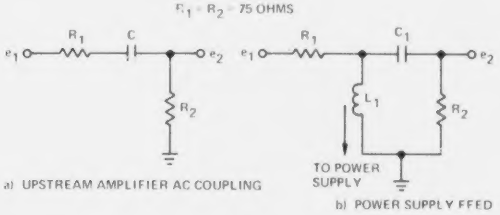
Much attention has been given the FDM chroma delay problem at the upper edge of the upstream band and lower edge of the downstream band. However, the low frequency delay response of components in the upstream path can have a considerable effect on channels T-7 and T-8. As an example of the occurrence of this chroma delay, two fundamental circuit arrangements are analyzed. These circuits, plus variations of these circuits appear many times in an amplifier and/or passive component. More specifically, these circuits are the cause of low end upstream channel chroma delay in the following cable system equipment.

Directional Couplers
Line Splitters
Intermediate Bridger (Thru Path)
Directional Taps
Upstream Repeater Amplifiers
Repeater amplifier motherboard (or module interconnect chassis) in 60 Hz power feed and tapoff circuit.

The number of such components in cascade can cause T-7 chroma delay which is equal to or greater than that due to FDM filters in other channels.

Typical networks which appear in these components are shown in Figure 7.

As an example of the values of delay resulting from these types of networks, calculations using some sample values are summarized in Table 3.



a) UPSTREAM AMPLIFIER AC COUPLING

b) POWER SUPPLY FEED

FIGURE 7

Figure 7 Circuits which can be source of group delay distortion in low subchannels.

TABLE 3

CIRCUIT (A) C = .01 uf			CIRCUIT (B) L_1 = 5uh C_1 = .02 uf	
FREQ MHZ	e_2/e_1 dB	DELAY NSEC	e_2/e_1 dB	DELAY NSEC
7	-6.02	1.37	-6.13	4.08
10.58	-6.01	0.60	-6.07	1.78
13	-6.00	0.40	-6.05	1.18
16.58	-6.00	0.25	-6.04	.72

Unfortunately, a conclusion on specific delay values for each of the components listed on page 10 cannot be reported at this time because a large enough sample of each component was not available. However, delay measurements made on each item available indicated that the chroma delay through a cable system could be significant in channel T-7 (picture carrier 7 MHz, chroma carrier 10.58 MHz). Typical values of channel T-7 chroma delay measured on a small sample of each item is listed below. Because of the small sample size, these numbers may not be representative of products now on the market. The bandwidth of the components tested were specified as 5-300 MHz by the manufacturers.

ITEM	CHROMA DELAY (NSEC)
2-output line splitter	2.5
4-output line splitter	10
Directional Taps	3
Intermediate Bridger	5
Trunk Amp Motherboard	3
Upstream Amplifier (IC, no equalizer)	Negligible

FDM FILTERS

FDM Filters for the sub-low frequency split (5-30 MHz, upstream, 54-300 MHz downstream) must simultaneously meet a number of performance parameters. The filter design is a compromise of the following parameters:

rate of cutoff
minimum stop band attenuation
minimum ripple in passband
minimum insertion loss in passband
high return loss in passband
constant group delay in passband

The group delay characteristic of the FDM filter will depend not only on what design compromise is made, but also on the filter alignment and practical filter component values. Estimated ranges of chroma delay values which might be expected from a pair of FDM filters (one pair per amplifier station) are listed in Table 4. The group delay will depend on the specific filter design, which each manufacturer must specify. The estimated delay values are based on filter designs which are necessary to simultaneously realize performance for each of the six parameters listed above.

TABLE 4
RANGE OF CHROMA DELAY VALUES IN NSEC FOR PAIR (2) OF FDM FILTERS

CHANNEL	LOW PASS FILTER (2)	HIGH PASS FILTER (2)
T-7	+1 to +2.0	
T-8	+3 to +5.4	
T-9	+3.4 to +6	
T-10	+10 to +20	
2		−4 to −8
3		−3 to −5

System Chroma Delay
The system chroma delay of a channel can be estimated by adding the chroma delay of the channel due to each component in the transmission path between sending and receiving location. As discussed in previous pages, the chroma delay of each channel can be caused by a number of different components. A summary of the sources of chroma delay and the channels affected is shown below.

CHANNEL	FREQUENCY	MAIN SOURCES OF CHROMA DELAY
T-7	7-10.58	Directional Couplers Directional Taps Line Splitters AC Coupling to Upstream Amplifier Intermediate Bridgers Repeater Station Motherboard Power Supply Coupling
T-8	13-16.58	
T-9	19-22.58	FDM Filters
T-10	25-28.58	Cable Equalizers
2	55.25-58.83	FDM Filters
3	61.25-64.83	
4	67.25-70.83	

Testing for Chroma Delay

One method of testing for chroma delay is the use of a modulated 20T or 12.5T pulse as described in Reference 8. This is a single channel test which requires use of a demodulator, since the test equipment is designed to operate at baseband video frequencies. Waveform testing, in addition to the modulated 20T or 12.5T pulse, may be necessary to insure that a given channel delay characteristic (equalized or not), does not impair the total channel waveform beyond an acceptable limit.

Swept delay measurements of a transmission path would be desireable if the test equipment was available. Further discussion of testing for chroma delay is beyond the scope of this paper.

System Delay Distortion Correction

Each component in the 2-way cable system should be designed to minimize its contribution of delay distortion. However, constant group delay per television channel, per system component, many times cannot be met simultaneously with all of the other required operational characteristics of the system component. A given amount of delay distortion will therefore be present in a transmission path after the compromises of cost effective component design and design tradeoffs between delay distortion, frequency response, insertion loss, etc., have been selected. So the next question is "what methods or techniques can be used to reduce transmission path delay distortion from that caused by the components in the transmission path, when these components are considered to be optimum from a total performance and cost standpoint?". Two methods will be considered. Either one, or both, may be required to solve a specific delay distortion problem. One method requires selection of channel frequencies in the forward and reverse transmission path and the second method requires the addition of delay equalizers in the transmission path.

Method One - Channel Frequency Selection

Channel frequency selection may be effective when downstream low band channels are available and can be used to transmit any upstream channel which has suffered delay distortion back into the downstream system path. If low band channels are not available, then some other method of delay equalization may be used.

Consider the delay characteristics of a single low pass filter and high pass filter as shown in Figure 8. As an example of how channel frequency selection can reduce total transmission path delay distortion, the simple system of Figure 9 will be analyzed. An upstream channel, T-9, applied to the low pass filter, acquires the delay characteristic of the low pass filter over its channel bandpass.

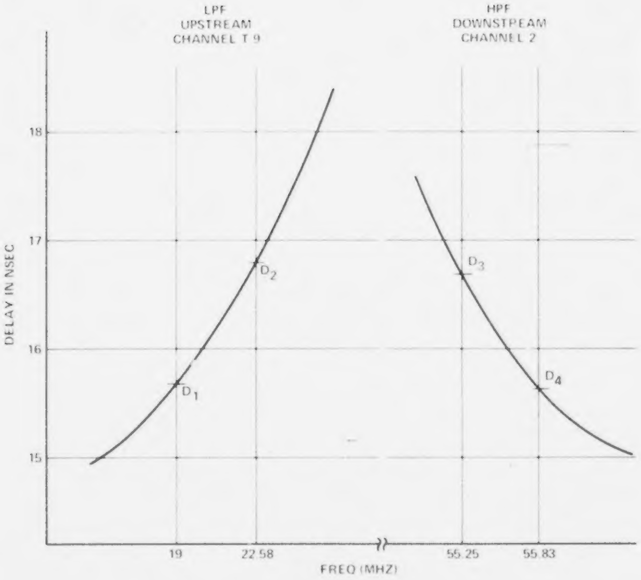
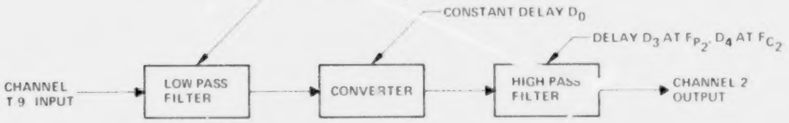


FIGURE 8 GROUP DELAY OF C06-05-44 FDM FILTER PAIR

Channel T-9 is then converted to Channel 2 in a converter located at a hub or the headend. The converter is assumed to have a constant delay versus frequency characteristic over the channel bandwidths. The delay of the video and color subcarrier frequencies passing through the high pass filter have an inverse delay characteristic compared to the low pass filter as shown in Figure 8. That is, the relative delay at the


DELAY D_1 AT F_{P_1}, D_2 AT F_{C_1}
CONSTANT DELAY D_0
DELAY D_3 AT F_{P_2}, D_4 AT F_{C_2}
CHANNEL T 9 INPUT
LOW PASS FILTER
CONVERTER
HIGH PASS FILTER
CHANNEL 2 OUTPUT

	FREQ (MHz)
F_{P_1}	19
F_{C_1}	22.58
F_{P_2}	55.25
F_{C_2}	58.83

FIGURE 9 TRANSMISSION PATH DELAY DISTORTION REDUCTION BY CHANNEL FREQUENCY SELECTION

luminance and chrominance carrier frequencies are reversed between the low pass and high pass filter. The inverse characteristics will match in much the same manner that a cable loss equalizer matches the cable loss characteristic, and partial delay equalization can be obtained. An example of the amount of delay equalization available, using delay values obtained from Reference 2 follows.

The picture carrier of channel T-9 experiences a delay D_1 thru the LPF. Since we are interested in the delay difference between picture and chroma carriers, constant delays at each frequency are not important. After conversion from T-9 carrier frequency to channel 2 carrier frequency, the picture carrier experiences an additional group delay thru the HPF equal to D_3. The picture carrier delay thru the entire system shown in Figure 8 is now $D_1 + D_3$ plus the constant delay of the converter.

The chroma carrier of channel T-9 is delayed by D_2 in the LPF and after conversion to channel 2 chroma carrier frequency is delayed by D_4. The chroma carrier delay thru the entire system is now $D_2 + D_4$ plus the same constant delay of the converter.

The chroma delay of the channel 2 (converted from T-9) signal is equal to $(D_2 + D_4) - (D_1 + D_3)$. The delay values are summarized in Table 5.

The low pass filter and high pass filter designs are referred to as C06-05-44 in Reference 2. The delay values for D_1, D_2, D_3, D_4 were derived from a graph on Page 176 of Reference 2. The LPF cutoff frequency is 35MHz and HP cutoff is 45 MHz. Note that delay equalization for this example greatly reduces the chroma delay of the transmission path.

TABLE 5
SUMMARY OF DELAY EQUALIZATION BY CONVERSION
C06-05-44 FILTER

	SUBCHANNEL T-9		LOW BAND CHANNEL CH. 2	
CARRIER FREQ (MHZ)	PICTURE 19	CHROMA 22.58	PICTURE 55.25	CHROMA 58.83
DELAY (NSEC) CHROMA DELAY	D_1 15.7	D_2 17.3	D_3 16.7	D_4 15.5
SUM OF DELAY (AFTER CONVERSION)	$\underbrace{D_1 + D_3 = 32.4}_{\text{PICTURE}}$		$\underbrace{D_2 + D_4 = 32.8}_{\text{CHROMA}}$	
CHROMA DELAY AFTER EQUALIZATION BY CONVERSION	$(D_2 + D_4) - (D_1 + D_3)$ = CHROMA DELAY 32.8 – 32.4 = 0.4 NSEC			

Proceeding on to further methods of transmission path delay equalization, the following items will be discussed:

Delay Equalization of upstream channel received at Head End.
Delay Pre-Equalization of channels at Head End and example of cascade group delay accumulation.
Shape of channel 2 delay characteristic due to broadband cable repeater high pass filter.
Linear delay equalizer.
Test results of cascade group delay equalization.

Delay Equalization of Upstream Channel Arriving at Head End

To correct the delay distortion caused by an upstream signal path on a given channel, a delay equalizer can be placed at any of a number of points in the Head End signal processor chain.

Referring to Figure 10, delay equalization of a single upstream channel will be described. The received upstream channels are separated from the downstream channels by means of a low pass filter (LPF). Assuming use of a single channel converter, the received upstream channel is converted to a standard television channel, such as channel 2 or channel 3. The signal can now be applied to a standard heterodyne signal processor. Delay Equalization can be accomplished either at i-f frequencies or at r-f frequencies. Delay equalization at i-f frequencies is convenient, since a single set, or family of delay equalizers can be designed to accommodate all channels, rather than a set of delay equalizers for each channel. Delay equalization at i-f frequencies is shown in Figure 10, where the heterodyne i-f amplifier output is fed to a delay equalizer rather than directly to the upconverter input. On the other hand, since only a few channels should need delay equalization, it can be done at the actual channel frequencies.

The block entitled IF DELAY EQUALIZER could alternately be placed at the UPCONVERTER output. The delay equalizer is designed to provide various combinations of equalization as discussed next.

The delay equalizer can provide an equalized signal output which has minimum delay error. This signal can be used locally at the head end or fed to another transmission path which does not introduce unacceptable delay distortion. Signal output #1 of Figure 10 would be used for this purpose.

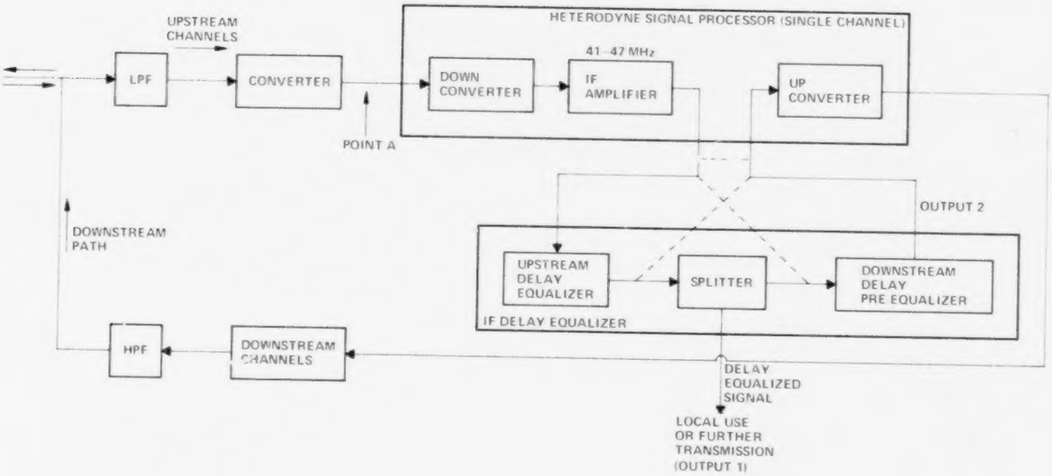

UPSTREAM CHANNELS
LPF
CONVERTER
HETERODYNE SIGNAL PROCESSOR (SINGLE CHANNEL)
DOWN CONVERTER
41–47 MHz
IF AMPLIFIER
UP CONVERTER
POINT A
OUTPUT 2
DOWNSTREAM PATH
UPSTREAM DELAY EQUALIZER
SPLITTER
DOWNSTREAM DELAY PRE EQUALIZER
IF DELAY EQUALIZER
HPF
DOWNSTREAM CHANNELS
DELAY EQUALIZED SIGNAL
LOCAL USE OR FURTHER TRANSMISSION (OUTPUT 1)

FIGURE 10 BLOCK DIAGRAM OF HEAD END, DETAILING ONE ARRANGEMENT OF ROUND TRIP GROUP DELAY EQUALIZATION

After the received channel has been delay equalized, it can then be fed thru a delay pre-equalizer for transmission back into the system on the downstream path. Output #2 of Figure 10 refers to this signal.

If desired, the upstream delay equalizer can be bypassed and the delay equalizer used for pre-equalization only. This arrangement can be used to provide delay pre-equalization for channels received off-the-air.

Delay Pre-Equalization of Channels at the Head End

The use of delay pre-equalization was mentioned in the last section. Delay pre-equalizations means that a predetermined amount of delay distortion is added to a channel at the head-end or at a signal input point. The sense, or shape of the pre-equalization delay curve is the negative of the delay curve which the signal will experience in passing through the system. An example of the results which can be expected by the use of delay pre-equalization are shown in Figure 11.

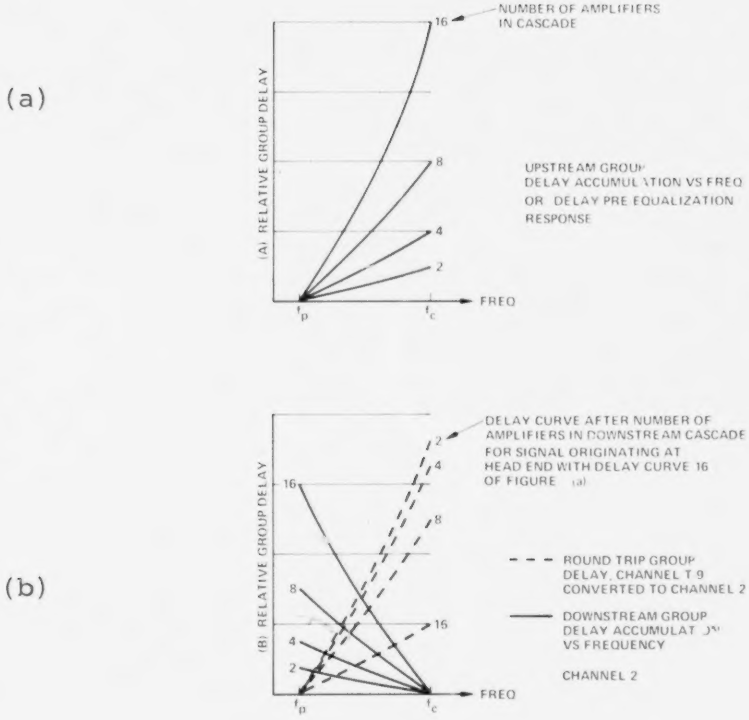


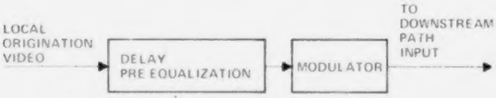
FIGURE 11 PRINCIPLE OF DELAY EQUALIZATION THRU 2-WAY TRANSMISSION AMPLIFIER CASCADE

A set of single channel delay curves is shown in Figure 11 (a). These delay curves could be the delay generated in a channel passing through the upstream path, or, they could be a set of delay curves generated by a delay pre-equalizer in the head end at the downstream channel frequency. If it is due to the upstream path delay, then this channel can be converted to a set of downstream channel frequencies. The delay curve is preserved thru this frequency conversion.

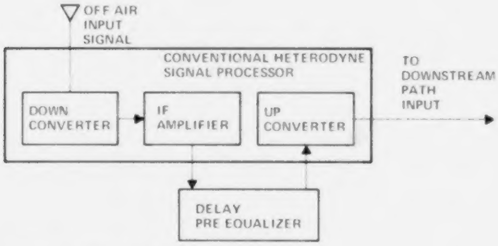
In Figure 11 (b), the dashed delay curve represents the channel delay as the signal proceeds thru a downstream path which introduces delay which is shown by the solid curve in Figure 11 (b). Note that after the 16th amplifier in the downstream path, the delay variation of the downstream channel as shown by the dashed curve is reduced compared to the delay variation caused by the downstream transmission path alone.

Block diagrams of methods to delay pre-equalize channels originating at the head end are shown in Figure 12. Delay pre-equalizers can be designed at video, if, or the actual r-f frequency of the desired channel. Equalization at if or rf frequencies may be more effective than video delay equalizers because of the FDM delay characteristics. (Refer to Figure 3).

Block diagrams of delay pre-equalizing upstream channels are shown in Figure 13. The upstream delay pre-equalization magnitude can be greater than that of a downstream channel, since the upstream channel will normally not be viewed or used until it reaches the head-end or hub. Therefore, an amount of delay pre-equalization which would cause objectionable viewing quality pictures could be introduced at the upstream signal input location.


LOCAL
ORIGINATION
VIDEO
DELAY
PRE EQUALIZATION
MODULATOR
TO
DOWNSTREAM
PATH
INPUT

(a) HEAD END MODULATOR PRE EQUALIZATION


OFF AIR
INPUT
SIGNAL
CONVENTIONAL HETERODYNE
SIGNAL PROCESSOR
DOWN
CONVERTER
IF
AMPLIFIER
UP
CONVERTER
TO
DOWNSTREAM
PATH
INPUT
DELAY
PRE EQUALIZER

(b) OFF AIR SIGNAL PRE EQUALIZATION USING HETERODYNE SIGNAL PROCESSOR

FIGURE 12 BLOCK DIAGRAM SHOWING METHODS OF DELAY PRE-EQUALIZATION OF SIGNALS ORIGINATING AT HEAD END

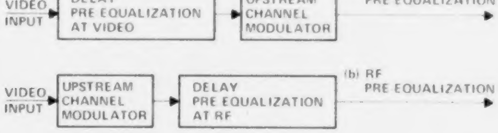

VIDEO
INPUT
DELAY
PRE EQUALIZATION
AT VIDEO
UPSTREAM
CHANNEL
MODULATOR
(a) VIDEO
PRE EQUALIZATION
VIDEO
INPUT
UPSTREAM
CHANNEL
MODULATOR
DELAY
PRE EQUALIZATION
AT RF
(b) RF
PRE EQUALIZATION

FIGURE 13 BLOCK DIAGRAM OF DELAY PRE-EQUALIZATION AT UPSTREAM SIGNAL INPUT LOCATION

Channel 2 Group Delay Characteristics

A group delay characteristic over channel 2 frequency band is shown in Figure 14. This curve was calculated by a circuit analysis program developed by Anaconda Electronics.

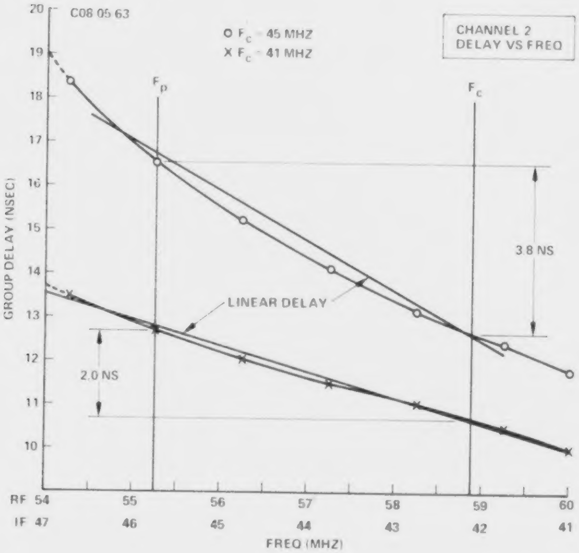


FIGURE 14 CALCULATED GROUP DELAY IN CHANNEL 2 FOR TWO FILTERS OF SAME DESIGN BUT DIFFERENT CUTOFF FREQUENCY

The filter analyzed is referred to as C08-05-63 and was taken from page 286 of Reference 5. It is an eighth order filter with design values to realize a 26dB passband return loss. Inductor Q's = 200 were used and the cutoff frequency of the filter was 41 MHz for curve A and 45 MHz for curve B. The Anaconda Electronic Model 2153 FDM filter has a delay characteristic which falls between the two shown.

A straight line is drawn thru both curves to show how well the delay characteristic of a single filter approximates a straight line. The straight line, or linear, approximation of the delay curve is significant, since linear time delay network designs have been in use for other applications for many years. By using a linear time delay network with a slope equal in magnitude and opposite in sign to the filter characteristic, excellent delay equalization is obtainable.

LINEAR TIME DELAY EQUALIZER

A linear time delay network or section is shown in Figure 15. The total delay correction or pre-equalization required will determine the number of sections required.

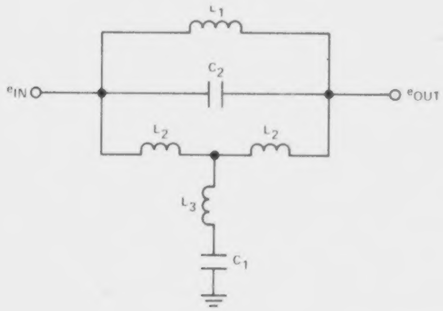


FIGURE 15 SCHEMATIC OF LINEAR TIME DELAY, ALL PASS NETWORK

This type of network is designed to have a flat amplitude response and linear time delay (quadratic phase) response over a given frequency band. It is effective over a single television channel. However, it can be designed to cover more than a single television channel. Calculated delay values for a single section of network similar to that shown in Figure 15 are listed below. This network was used to equalize the group delay variation of the channel 2 band through a cascade of ten FDM filters (5 amplifier cascade). The delay characteristic of the network built was shifted slightly in frequency from those values in the Table 6.

TABLE 6

CALCULATED DELAY EQUALIZER RESPONSE

FREQ (MHZ)	PHASE (DEGREES)	DELAY (NSEC)
54.25	39.5	13.5
55.25	44.9	17.0
56.25	51.8	21.8
57.25	60.8	28.6
58.25	72.8	38.6
59.25	89.2	53.1
60.25	111.6	72.5

Test Results of Delay Equalizer Network

Ten Anaconda Electronics Model 2153 filters were connected in cascade and the group delay versus frequency response measured on a General Radio Type 1710 analyzer system. The response of this cascade is shown in Figure 16(a). The vertical scale is 10 ns per large division and the horizontal scale is 1.0 MHz per large division. The center of the horizontal scale is 55 MHz. Two delay network sections (networks similar to that shown in Figure 15) were constructed. The delay response of these two sections is shown in Figure 16(b).

The delay response of the ten filter cascade plus a single delay network section is shown in Figure 17(a) In Figure 17(b) is shown the ten filter cascade plus two delay sections in cascade. Note that a reduction of Channel 2 chroma delay from 28 ns to 10 ns is achieved. By varying element values of the delay equalizer networks even better equalization can be attained.

Conclusion

If the assumption that a shaped chroma delay of 178 nanoseconds will result in an acceptable, saleable, picture, then the following conclusions can be made.

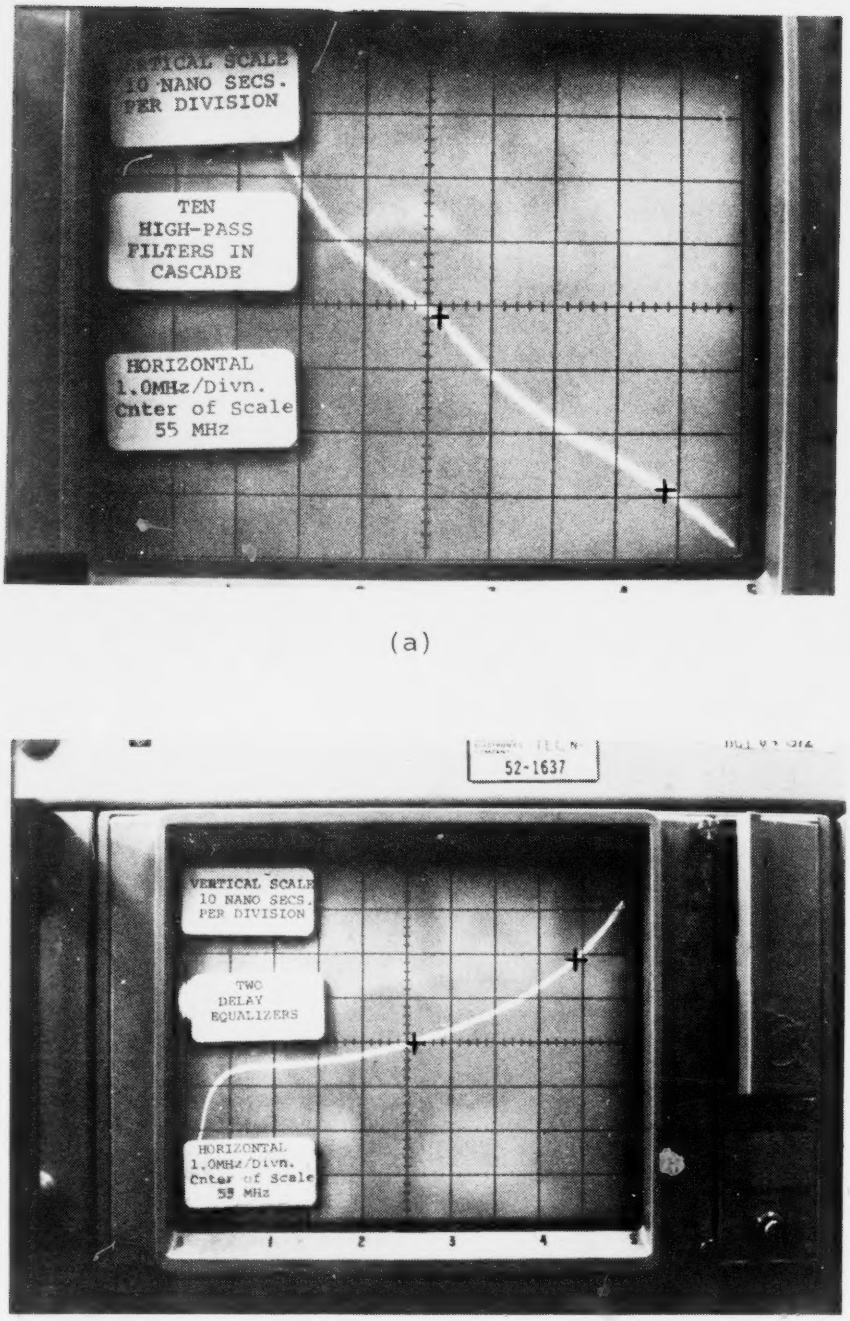
Upstream Path

The chroma delay of a channel can far exceed 178 nanoseconds if the channel is appropriately delay equalized before final viewing or further transmission. This is possible because the signal will probably be received at a single, or at most, a few locations, so that delay equalization at the receiver is practical. Chroma delay of the upstream cable path will be negative for Channel T7 (chroma carrier has less delay than picture carrier) and positive for Channel T-10 (chroma carrier has more delay than picture carrier). Chroma delay of Channels T8 and T9 may be either positive, negative, or U-shaped, depending on components used in system.

To estimate the upstream delay on Channels T-8, T-9, and T-10, the upstream FDM filter chroma delays and upstream amplifier chroma delays should be known. The chroma delay of Channel T-7 can be estimated when the chroma delays of the total number of components (listed on Page 10) in the path is known.

Downstream Path

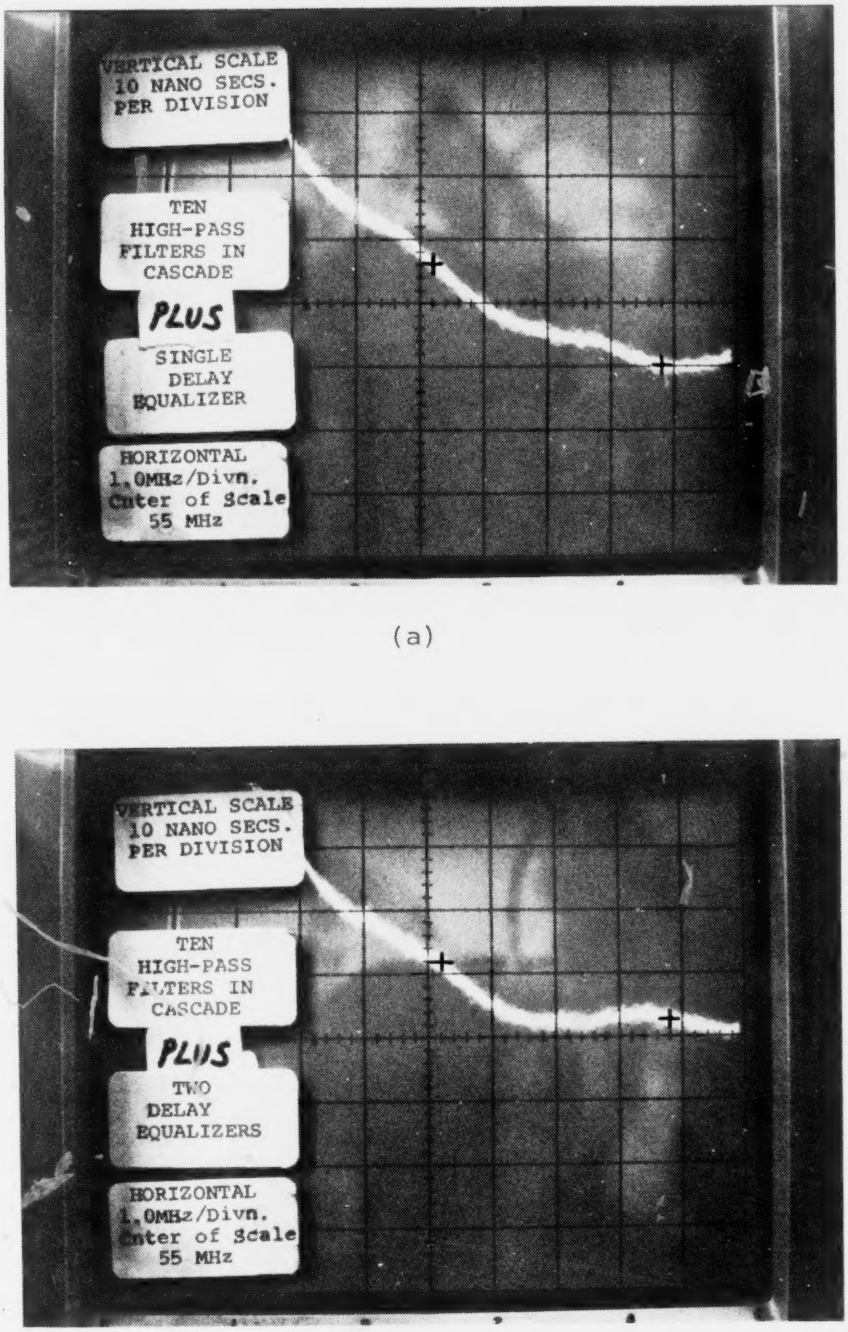
Total allowable downstream path delay can be 354 nsec if 178 nsec of delay pre-equalization is inserted in the signal path at the head end. Because of the multi-receiver locations along the downstream path, delay equalization at the receivers is not practical at this time.



(a)

(b)

FIGURE 16 a) Group delay versus frequency of cascade of ten (10) high pass FDM filters
b) Delay response of two delay equalizer sections



(a)

(b)

FIGURE 17 a) Delay response of 10 filter cascade plus single delay equalizer section
b) Delay response of 10 filter cascade plus two delay equalizer sections

Downstream delay pre-equalization can be accomplished either by conversion of the upstream channel with suitable delay characteristic or a delay network equalizer, or a combination of both.

The downstream path delay is easier to predict than the upstream path delay, since the predominant delay contribution is due to the FDM filters.

If delay equalization is used, care must be taken to insure than an acceptable delay characteristic across the channel bandwidth is attained.

Video waveform testing in addition to a modulated 20T or 12.5T pulse test may be necessary.

Acknowledgement
The efforts of Jere Friske in building and testing numerous circuits and CATV products were helpful in gathering information for this paper.

APPENDIX I

Delay Characteristics of Low Loss Cable

The complex propagation constant of a transmission line is

$$\gamma = (R+jwL) \quad (G+jwC) \qquad (1)$$

The quantity (R+jwL) is the equivalent series impedance per unit length, and (G+jwC) is the equivalent shunt admittance per unit length. The real part of γ is the attenuation constant per unit length, and the imaginary part of γ is the phase shift per unit length.

For a low loss line, $R \ll wL$ and $G \ll wC$. Using these approximations and the binomial expansion, the imaginary part of (1) becomes:

$$B = W\sqrt{LC}\left[1+ 1/8\left(\frac{R}{WL}\right)^2\right] \qquad (2)$$

Equation (2) is the phase shift constant of a low loss line. By taking the derivative of B with respect to W, the group delay of the low loss cable becomes:

$$T_d = \frac{dB}{dw} = \sqrt{LC}\left[1 - 1/8\left(\frac{R}{WL}\right)^2\right] \qquad (3)$$

Note that this term is not independent of frequency, and therefore all frequencies are not delayed by the same amount. However, the variation in delay over a 4.2 MHz bandwidth is so small for the cable presently used in CATV systems that the effects of this delay distortion can be ignored. As a numerical example, equation (3) is evaluated for a sub-low and low band channel. The results are listed on page 8. Typical cable constants are:

Velocity of Propagation

$$V_c = .82V_o = \frac{1}{\sqrt{LC}} = 7.87 \times 10^8 \text{ ft/sec}$$

V_o is the velocity of propagation for free space.

Capacity per foot C = 16.5 pf/ft (Both 500 and 750 cable)

Cable attenuation at 68°F

500 Cable .243dB/100ft at 10 MHz, .59dB/100ft at 55 MHz
750 Cable .166dB/100ft at 10 MHz, .41dB/100ft at 55 MHz

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ELIMINATION OF CROSS-MODULATION IN CATV AMPLIFIERS

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Introduction

In this paper we will show how increased channel loading and output capability affects the performance levels of future CATV amplifiers. The expected operating levels of the transistors used in CATV amplifiers tomorrow is shown to be much greater than in the past. Transistor non-linearities causing cross-modulation, second order and triple beat forms of distortion, are discussed in light of increased peak output capability. A new transistor design and its performance in a discrete CATV amplifier circuit is presented.

1. How expansion of channel loading affects CATV amplifier and transistor design.

A review of the history of cross-modulation specifications would appear in order at this point and is shown in Table I. Note that early systems were specified for 9 to 12 channel capacity. The trend since 1964 has been to add pilot, FM, mid and superband channels. The previously shown cross-mod specification necessitates not only higher output capability, so that more amplifiers can be cascaded, but also necessitates increased channel capability. Let's take a closer look at how channel loading affects not only amplifier design but the design of transistors used in those amplifiers. Applying the specifications given for the 1964 amplifier, the peak output power capability per channel is calculated as follows:

Single channel output levels into 75 ohms
+42 dBmV (=) 126 mV (=) 1.68 mA RMS
Average power $= E \times I = 211\ \mu W$
Peak power $= \sqrt{2}\, E \times \sqrt{2}\, I = 422\ \mu W$

When more than one channel is present, and, depending upon the phase relationship between the signals present at only one instant in time, the peak output power can exceed the calculated level for a single channel. Although the average power of the output signal is the sum of the average power of each signal present, the peak output power can be several times the average power. We will now see how peak envelope power levels of the 9 channel amplifier compare with today's and tomorrow's amplifier.

Table II gives the calculated output peak voltage, current and

Table I

History of cross-modulation specifications for an all-band transistor mainline amplifier

Channel loading (flat response)	dBmV output capability for -57 dB XM		
Year	1964	1968	1972
9	42		
12	41	48	56
20		46	
35			50

Table II

Peak CATV amplifier output levels for -57 dB XM

Channel loading and level into 75 ohms	Volts (V)	Current (mA)	Power (mW)
9 ch @ +42 dBmV (1964)	1.6	21.4	34.
20 ch @ +46 dBmV (1968)	5.66	75.3	426
35 ch @ +50 dBmV (1972)	15.6	209	3300

power specifications for the amplifiers previously mentioned in Table I. The requirements for increased capacity and output level dramatically increased the peak levels of voltage, as shown in Fig. 1, and power in Fig. 2. It can be expected that the operating levels of the output semiconductors of newer amplifiers will have to provide these peak levels in addition to being linear. The nomograph in Fig. 3 allows us to take a quick look at what the very minimum operating points of a device would have to be. Besides offering second order cancellation, a push-pull output stage provides better efficiency for an additional 3 dB output capability. Assuming a push-pull output stage was needed to meet the 35 channel operating level of +50 dBmV, we next choose the collector load line impedance we expect to operate on. Since the curve was initially constructed for 12 channel operation, the output level contours must be corrected by approximately 5 dB to represent peak device requirements for 35 channel operation. The output contour is thus determined to be (+50 -3 +5) +52 dBmV. On the nomograph the 150 Ω collector load intersects the +52 dBmV locus at V_{CE} = 9.5V and I_C = 65 mA.

In addition to these specifications the end item user expects improved noise figure and efficiency so that he may be able to cascade more amplifiers and lower his cost per mile. Cost and reliability are always important in consumer service and these factors find their way back to the equipment and component manufacturer as tougher specifications.

As a semiconductor manufacturer TRW has been providing discrete devices and hybrid function modules specifically to the CATV industry for several years. The realization of the increased need for output capability, which we have just shown, caused TRW to accelerate its intensive R&D effort on the development of transistor devices capable of meeting the future industry needs while continually upgrading present products. To do this we started our investigation at the beginning; the design of a high power, high frequency, linear amplifier.

Once an amplifier is designed it is constructed with mostly passive components. Resistors, capacitors and inductors used in CATV amplifiers are normally linear devices and do not directly contribute to the resulting distortion levels. The most generally applied technique for lowering distortion is the application of negative feedback. Since we know the feedback will reduce distortion, stabilize operating point, and increase frequency response, we expect that some form of feedback will be used. If a single stage, for example, exhibits 1% distortion and we can apply 10 dB of feedback, the distortion and gain is reduced by 10 dB. It's obvious that it would be better to have 0.1% distortion to start with and reduce that initial level by 10 dB with the feedback. The approach taken by R&D at TRW has been to provide the semiconductor division with the design of an ultra-linear transistor with increased dynamic range. This device design has set new standards of performance in the reduction of distortion in the form of cross-modulation, second order and triple beat. In order to develop this highly linear microwave transistor, an in-depth investigation into all of the non-linearities of a bipolar transistor was initiated.

2. Transistor non-linearities

2.1 Relationship of output capability and dynamic load line

The minimum transistor bias requirements for the above mentioned +50 dBmV output capability were presented in Fig. 3. Next we transfer the bias point (A) to a set of over-idealized transistor transfer characteristics and construct a dynamic load line, slope equal to -1/RL, with the expected peak voltage swings, Fig. 4a. Having completed this operation it becomes apparent that when the signal swings positive, increasing voltage, it will transverse to a V_{CE} voltage of zero, provided the device had no limiting resistance. However transistors, like tubes, have their limitations. A slightly more representative set of device curves with a load line is shown in Fig. 4b. Note that for the same bias point, when the signal swings positive, it will transverse into a very nonlinear current region and when decreasing, the signal will be limited by the saturation resistance of the device. These nonlinear regions, cutoff and saturation, cause severe clipping of the signal and can be avoided by increasing the bias current and voltage to the point C where the expected voltage and current swing is well within the capability of the device. All quality CATV amplifiers are designed with bias points well within the device characteristics and are analyzed over the expected temperature range to insure bias point stability.

2.2 Temperature variation

The temperature of the active portion of the device is given by,

$$T = (P_{bias} + P_{signal})\theta_{jc} + T_s$$

and

$$dT = (dP_b + dP_s)\theta_{jc}.$$

We have chosen the bias point and load line to follow a constant power contour so that $dP_b = 0$. The impact of synchronous multichannel operation is seen in that dP_{signal} is the power in a single channel times the number of channels. The relative change in temperature is then:

$$dT/T = -NdP_s\theta_{jc}/(V_C I_C \theta_{jc} + T_s),$$

since P_{signal} is initially zero and dP_b is made zero by the choice of load line. The change is negative since power is removed via the output signal. The change in dB relative to the operating temperature is plotted versus output level for 9, 12, 20, and 35 channels in Fig. 5. The impact of this change on various parameters can be significant at low cross-modulation levels. For example, Fig. 6 shows the temperature variation in resistivity of typical collector and base material.

2.3 Collector non-linearity

Nearly all CATV amplifier circuits are designed to have minimum capacitance (junction, metal, stray) projected across the collector circuit in order to obtain the wide bandwidths required. However there is another reason to minimize the output circuit capacity. Where a high frequency signal is present, the collector will see a reactive load. Owing to the angle between the sinusoidal current and voltage in reactive loads, the collector current will not have the same value for increasing collector voltage that it has for decreasing voltages. The load line is a form of an ellipse, varying from a straight line for a pure resistive collector load to a circle for loads of pure reactance. Fig. 7 shows that for extreme swings the elliptical load line can swing into nonlinear regions of the device. Microwave power transistors exhibit two fixed output capacitances plus junction and stray capacitances which degrade second order, cross-modulation, and triple beat performance.

We have discussed the importance of minimizing fixed capacitance to reduce the elliptical load line. The forms of fixed capacitance significant in bipolar transistors are metal over oxide (MOS) and header or case capacitance. Great care has been taken by semiconductor manufacturers in the design of their devices to reduce the area of metallization over silicon oxide and make the silicon oxide as thick as possible to reduce the basic chip capacitance. Since a poor package can often have much more stray capacitance than the chip exhibits, new stripline packages with low parasitic lead inductance, case capacitance, and excellent thermal characteristics were developed.

The properties of any semiconductor junction are a function of the voltage across it and the current through it. The collector-base junction capacitance is inversely proportional to the collector emitter voltage and barely independent of the collector current at the low level class "A" bias for linear CATV. A large V_{CE} bias is desired to minimize C_{ob} as well as dC_{ob}/dV_{CE}, the differential of C_{ob} with respect to V_{CE}.

The collector capacitance is the result of the parallel plate analogue of the widening collector-base depletion region. This widening gives rise to a non-linearity in the collector resistance, r_c, which is a resistor with length equal to the epitaxial thickness minus the junction depth and the depletion width. To minimize the resistance, the epitaxial layer should be barely thick enough to contain the depletion width plus a little cushion for second breakdown resistance. Again a large V_{CE} is desired to reduce r_c and to minimize dr_c/dV_{CE} since the depletion width variation is least at high V_{CE}.

The magnitude of C_{ob} could be reduced by using a higher collector resistivity; but that would be at the expense of the collector resistance and the allowable current density, which hasn't been a good tradeoff. Actually, device ruggedness requires thicker, higher resistivity epitaxial layers at the expense of performance.

As noted earlier, when power is taken from the device the temperature drops and the result is a decrease in r_c. This will be reflected as a decrease in $V_{CE(SAT)}$ and an increase in f_T, both of which cause a gain expansion and second order distortion.

2.4 Emitter-base non-linearities

There are two identified non-linearities associated with the emitter base junction, a shift in the contact potential, V_{BE}, and the multifaceted effects of temperature. The microwave transistors used in CATV amplifiers have the injection shift due to crowding from the bottom of the emitter to some point up the side, where the concentration and hence V_{BE} is higher. This shift in injection and V_{BE} is effectively suppressed at typical bias currents by the use of a shallow diffused emitter with a second contact. This forces injection at the bottom of the emitter away from the edge. It also avoids a premature roll-off of β and f_T with current as a result of a wider base when injection shifts up the side. The simple diode equation becomes:

$$I_e = I_o(T)\exp(qV/kT - \ln(N_{EBj}/Ni(T)^2))$$

and one realizes that saturation current, the nominal 26 millivolts, and the intrinsic concentration are all functions of temperature.

First order contribution of the base-emitter non-linearity to second and third order distortion has been observed and analyzed in several papers.[1,2] By observing the familiar ideal diode current-voltage relationship, Fig. 8, we would expect the distortion due to operation at about point A for a small excursion in base-emitter voltage to be very small as the curve at this point appears very straight. But, we are talking about distortion on the order of 100 dB down and that is approximately 0.001% non-linearity. Note the nonlinear exponential characteristic of current with respect to voltage, in the diode equation.

From the equations of Mallinckrodt[1] we have generated a family of curves representing the degree of second and third order distortion as a function of both emitter current and device current gain, Fig. 9, 10.

As can be seen from Fig. 10 it appears that the third order distortion term disappears at unique values of current gain and emitter current. (Mallinckrodt also shows this sharp null is dependent upon source resistance.) Two important factors obtained from Figs. 9 and 10 are the reduction in second and third order distortion due to low current gain and high emitter current. These conclusions are verified from our knowledge of the ideal diode current-voltage relationship shown in Fig. 8. Higher current gain implies lower base current drive (point B) operating in the more nonlinear base-emitter region. Likewise higher current requiring more base drive forces the device to operate in the more linear region of the base emitter junction characteristic.

2.5 Power gain non-linearity

Cross-modulation and other distortions are the result of a nonlinear power transfer curve. The factor relating the output power to the input power is the power gain of the transistor amplifier, which is given by,

$$P_g = f_T/8\pi f^2 r_b'C_c$$

The f_T is related to the low frequency beta by,

$$f_T = \beta_c f/(1 + jf/f_T).$$

It can be seen from the equation that not only does beta roll off with frequency, but there is also a phase shift. Upon expanding the power transfer curve into a power series, many of the coefficients normally considered real will be imaginary leading to additional null possibilities. The obvious design goal is a high f_T to reduce the beta roll-off and phase shift. For an f_T of 4 GHz the beta roll-off is pushed out past the superband and the phase shift is only a few degrees. The power gain is then:

$$P_g = \beta_o/8\pi f(1 + jf/f_T)r_b'C_c.$$

The negative temperature shift when signal power is removed reduces β_o resulting in a compression and cross-modulation. The effect of frequency will result in compression in the high band unless appropriate feedback is employed.

Of particular interest are the effects of I_C and V_C on the $r_b'C_c$ product. With increasing V_C, r_b' increases via base narrowing, giving rise to gain compression and C_c decreases giving rise to gain expansion. With increasing current r_b' can decrease, with base widening, giving rise to gain expansion. Increasing I_C can also decrease C_c for further gain expansion. If the magnitudes of the distortions are nearly equal and opposite, nulls can result from increasing V_C and be retraced as the result of increasing current. Shallow diffused processing with higher base concentrations reduces dr_b'/dV_{CE} and dr_b'/dI_C since there is less depletion of the collector-base junction into the base region. Again high V_{CE} lowers C_c and dC_c/dV_C.

2.6 S-parameter contour evaluation

The distortion parameters, previously described, characterize the device in terms of measured quantities, such as, h_{FE}, C_{ob}, etc., at lower than operating frequencies.

Muller indicated that a good measure of output capability, i.e., linearity, could be obtained by taking the forward S-parameters $|S_{21}|^2$ of a device over the expected current and voltage operating range and frequency. He showed that the more non-linear the $|S_{21}|^2$ parameter, forward transducer gain, the more output distortion would be present. Carrying this concept further, we can project a load line on the forward transfer characteristics $|S_{21}|^2$ to obtain a relative feel for its non-linear contribution. As an example Fig. 11 shows the $|S_{21}|^2$ parameter for a low-noise small-signal MATV device. The load line required for 35 channel output level intersects several constant contours indicating the relative distortion contributed by this parameter. The next figure represents the constant $|S_{21}|^2$ contours for a medium power microwave transistor normally used in a class C mode. Although its non-linear contribution is less than the previous device it is still too large to be of use in low cross-modulation amplifiers. In the analysis used at TRW to develop an ultra-linear RF transistor we have gone several steps further. These steps are the analysis of the behavior of all four S-parameters at band edges and over the expected operating range. The reason this somewhat elaborate analysis is taken, is to determine which of the previously mentioned non-linearities is the most dominant one at a particular operating point.

The $|S_{21}|^2$ contour of the CATV device shown in Fig. 12 exhibits much greater linearity over the load line than either of the two previously shown devices. The analysis now proceeds to the investigation of the effects of the other S-parameters. The S_{11} and S_{22} contours, shown in Fig. 13, represent the amount of signal reflected by the device at certain voltage and current bias points. Projecting a typical load line over these input and output characteristic curves and visualizing several instantaneous operating points we obtain a feel for the amount of distortion contributed due to the non-linear input and output behavior.

S-parameter characteristics allow us to measure the combined effects of collector-saturation, cutoff, current gain non-linearity, conduction modulation, etc., at the operating frequencies. By further analysis of these plots, using the ideas presented in the work of Linvill and Gibbons[3], we have been able to assign the dominant distortion contributing factors in the device. What we have learned through all of this analysis has been applied to the design of our almost totally cross-modulation free SLAM, a Super Linear And Microwave transistor.

3. The SLAM transistor

The SLAM transistor is a matrix pattern, which has an emitter like an expanded tic-tac-toe diagram with base contacts in the openings of the matrix or grid. The emitter perimeter to base area ratio is 7 for good microwave performance and operation over the CATV band. The photolithography of 0.1 mil lines and 0.07 mil space has produced good yields. As stated earlier the emitter is contacted through a final oxide layer rather than being contacted through the emitter diffusion opening as other microwave transistors are. This produces more linear operation by forcing injection uniformly across the bottom of the emitter.

Shallow diffusions with high base and emitter sheet resistances are employed to achieve better base transport. The steeper diffusion front of the shallow base diffusion also serves to reduce the collector-base depletion back into the base region. The highest collector concentration consistent with device ruggedness toward second breakdown and energy surge, further suppresses collector-base depletion back into the base region. The higher emitter sheet resistance, in conjunction with the contacted emitter pattern provides significant ballasting for balanced operation of this microwave transistor at CATV frequencies The metallizing on the device is currently a long-life nichrome-aluminum with more than adequate cross-sectional area and a glass overcoating to avoid electromigration and other reliability problems. A tungsten-gold metallizing system, for even longer operating lifetime is nearing completion in R&D.

4. Distortion performance of the SLAM in discrete CATV amplifier circuits

The proof of a successful transistor chip design is left in the hands of the circuit designer. That circuit designer usually has little or no knowledge of what has gone into the development of the device. Unique in the industry is the approach taken at TRW where device and circuit engineers work together toward a mutual understanding of the important distortion factors and their reduction.

To evaluate the performance of SLAM devices it was first necessary to characterize it by S-parameters as shown earlier. The parameter values were then combined with a circuit design computer program to optimize the feedback for gain flatness and input/output impedance match to 1000 MHz. Because the device exhibits considerable current gain phase shift over frequency small external matching elements are added to further improve flatness.

Initial cross-modulation performance of the design is shown in Fig. 14 thru 16. Device XM-28 had a 12 channel flat cross-modulation performance better than -65 dB on both channels 2 and 13. The figures indicate that the optimum voltage and current ranges for maximum performance are very broad and the device appears well behaved.

Mentioned previously were the possible effects of temperature and thermal modulation in producing cross-modulation. By lowering the junction temperature and forcing the thermal cross-modulation upward, there appears in cross-modulation/current curves an improvement in cross-modulation for 16 volt V_{CE} and bad behavior at 17 and 18 volts. This is due to the fact that some of thermal components of cross-modulation exhibit a phase term in their coefficient. The various phases change as a function of collector voltage, current, output level, temperature and frequency. It should not be suprising by now to imagine one instant in time an upward modulation caused by low-band signals and a downward modulation caused by superband signals resulting in an apparent cross-modulation level of -100 dB. This could also be accomplished by changing the form contribution of thermal modulation to null out base-emitter non-linearity. This was done as shown in Fig. 16 where the additive cross-modulation components at a poor bias point were modified by changing the duty cycle and repetition rate of the modulation. This reduced the thermal modulation effect of the junctions and resulted in cross-modulation level of -90 dB, Fig. 17.

It's apparent that the complex cross-modulation levels measured here do not reflect the cross-modulation produced only by a real third order non-linearity term. A truer indication of the magnitude of the third order contribution is obtained by measuring the triple beat performance of the device. The results of this test, Fig. 18, indicate that the triple beat characteristic was smooth, no nulling behavior, and that the best triple beat was close to the best cross-modulation level. We would expect that the triple beat level would be slightly more than 20 dB below the measured cross-modulation as shown by Simons[4]. This is if the cross-modulation is dominantly third order and phase independent.

It has been brought out by some that cross-modulation due to thermal modulation is not as important as triple beat performance. They argue that in actual usage the device will never experience synchronous modulation and therefore the thermal modulation contribution will be zero. We caution purchasers of equipment and devices against adopting this view. Besides the major networks many independents are using atomic clocks to derive their timing standards. This means that the chance of true synchronous modulation is ever increasing and that the worst case NCTA cross-modulation test for output capability is still a very valid one.

Although we've limited most of our discussion to cross-modulation effects, a device with only good cross-modulation is useless. Along with reducing cross-modulation we were able to design and control the device parameters to reduce second order distortion at a particular bias point. At some bias points the base emitter second order non-linearity will cancel the collector-base second order contribution giving a null or minimum in the distortion level as shown in Fig. 19. We are also able to guarantee this null point when the device is used properly over the complete operating band of frequencies. Of course as shown by the curves the relative width of the null for a given second order level is dependent upon both voltage and current bias points. Care must be taken by circuit designers to insure that the bias circuits are capable of providing the degree of bias stability required over temperature according to the level of performance desired.

A single stage transformerless amplifier design shown in Fig. 21 performed as follows:

Frequency response:	5 MHz to 1000 MHz
Gain:	7 dB
Gain flatness:	±0.5 dB
Cross-mod @ +50 dBmV:	-85 dB Ch 2 and Ch 13
2nd order @ +50 dBmV:	-76 dB Ch 2
	-72 dB Ch G
	-74 dB Ch 13
$V_{CC} = +24V$, $I_C = 100$ mA	
Return loss:	>16 dB 50-250 MHz

Two stages were combined to evaluate the additive effects on performance and to obtain a minimum gain of 15 dB over a somewhat smaller bandwidth. Because of the stray circuit elements the flatness and input match are not indicative of what can be obtained when this circuit is transformed to hybrid form where the parasitics are designed into the matching and gain flatness networks.

Two stage performance:

Frequency response:	5-1000 MHz	
Gain:	18 dB	
Gain flatness:	±0.5 dB	
Cross-mod ± +50 dBmV:	-82 dB	
2nd order @ +50 dBmV:	-66 all three channels	
$V_{CC} = +24V$, $I_C = 196$ mA		
Return loss:	>18 dB	50-250 MHz
	>16 dB	250-500 MHz
	>10 dB	500-1000 MHz

Next a four stage circuit was fabricated and exhibited the following characteristics:

Frequency response:	5-300 MHz
Gain:	30 dB ±0.5 dB
Cross-mod @ +50 dBmV:	-72 dB Ch 2
	-78 dB Ch 13
2nd order @ +50 dBmV:	-60 dB Ch 2
	-64 dB Ch G
	-64 dB Ch 13
N.F.:	9.4 dB Ch 13
$V_{CC} = 24V$, I_C total = 200 mA	

Return loss:	>18 dB	50-250 MHz
	>16 dB	250-500 MHz

5. Conclusions

This work serves to demonstrate that distortion (cross-modulation, second order, triple beat, etc.) in CATV amplifiers is caused by many mechanisms, all of which must be suppressed simultaneously to achieve the desired low levels of distortion. If one form of distortion is severe,suppression of all the others does not show in the result. If two forms remain significant and one is rising while the other is falling, as a function of voltage, current, frequency or temperature, nulls appear in the results. At TRW, we have identified (1) power loading as a cause of temperature variation, (2) signal swing around the dc bias as a variation in the instantaneous characteristic of the transistor, and (3) bandwidth as a frequency variation in the instantaneous characteristic of the transistor as the primary distortion producing mechanisms. We then designed the SLAM transistor to suppress the effects of temperature, V_C, and I_C on the transistor characteristic. Finally the circuit, to match the transistor, was designed to provide a flat response over the CATV band, to reduce the remaining distortion, and to compensate the phase over the CATV band via feedback. The transistor is packaged in a low parasitic stripline stud to preserve the thermal design.

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3. J.G. Linvill and J. F. Gibbons, Transistors and Active Circuits, McGraw-Hill, New York, 1961.
4. K. Simons, Technical Handbook for CATV Systems 3rd, Jerrold Electronics Corp., Philadelphia, 1968.
5. A. B. Phillips, Transistor Engineering, McGraw-Hill, 1962.

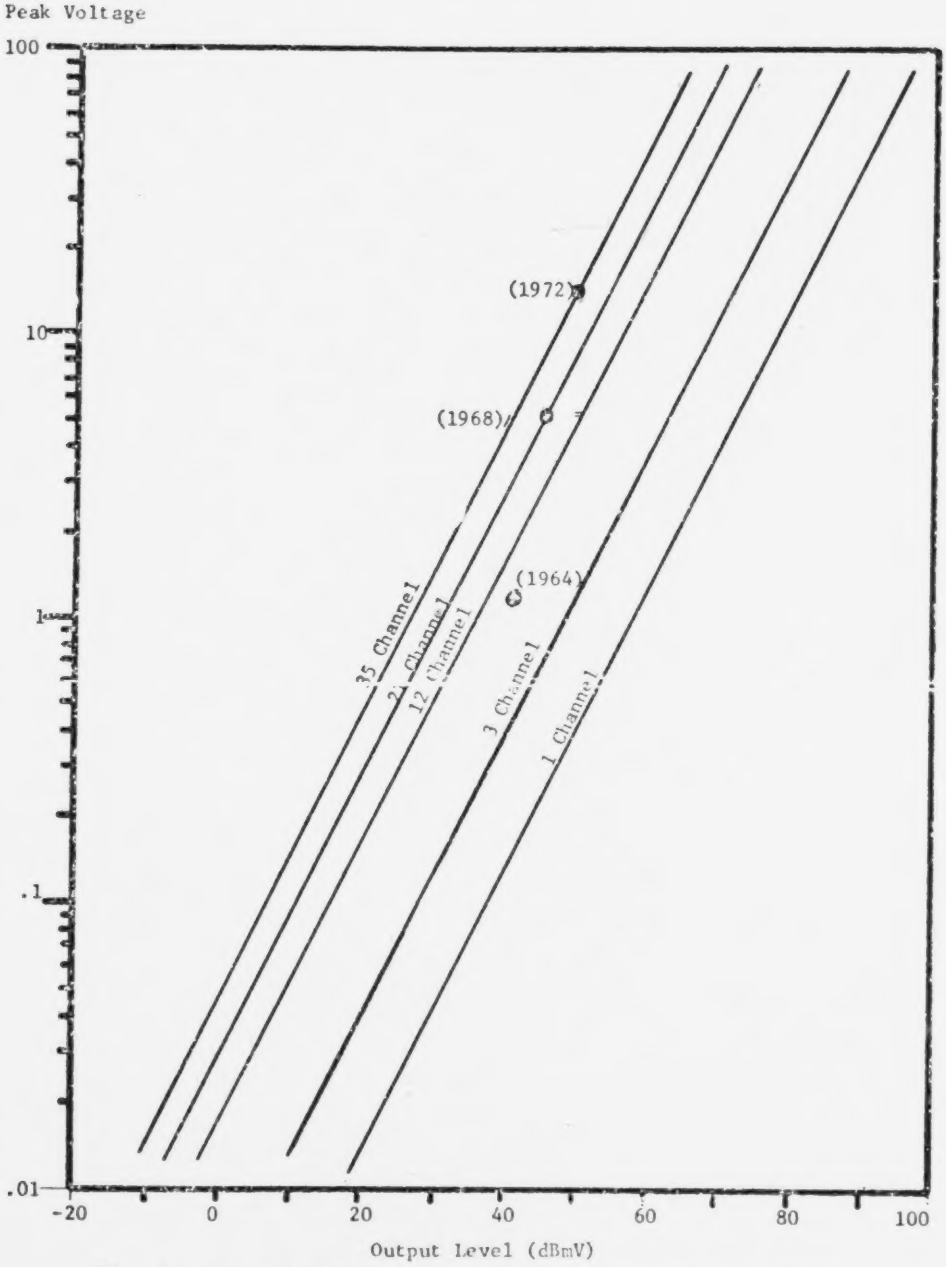


Fig. 1. Peak RF voltage across 75 ohms as a function of output level and channel loading.

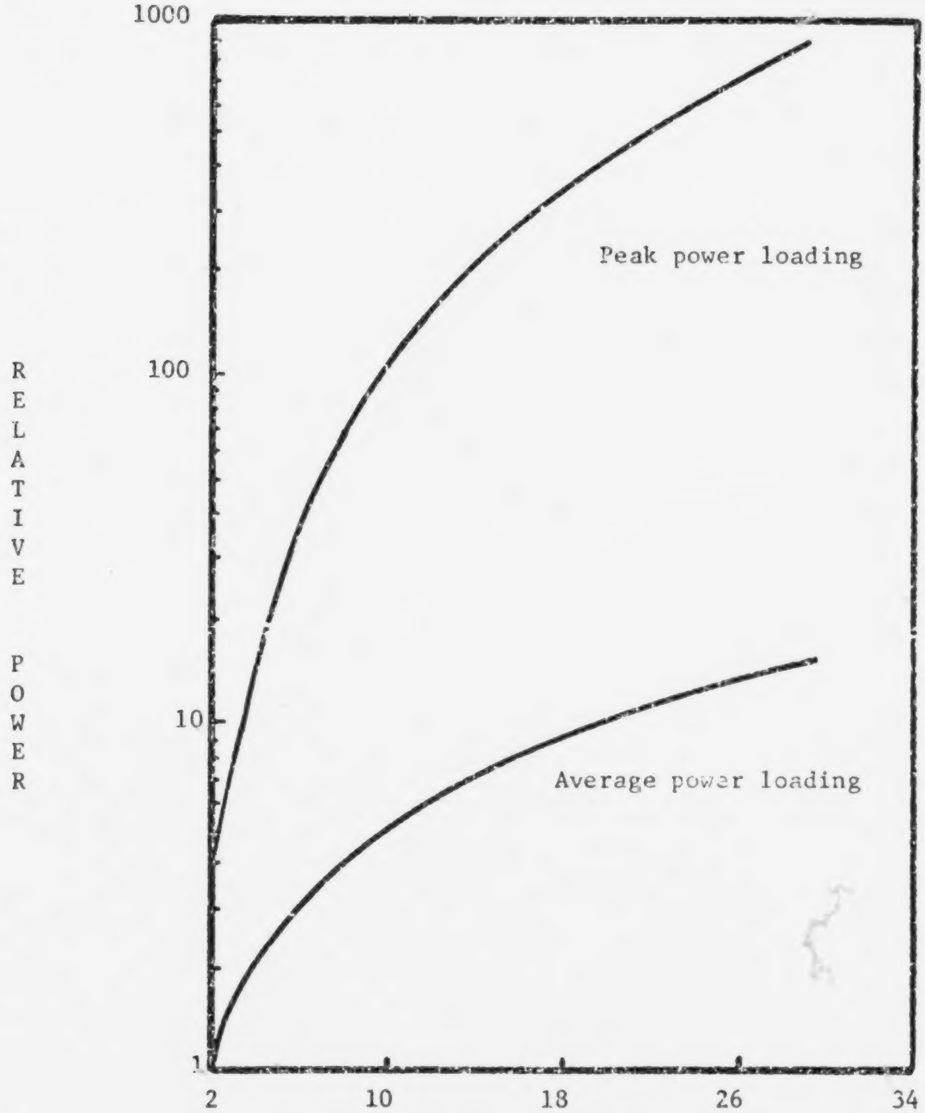


Fig. 2. Normalized peak and average power loading as a function of number of channels present.

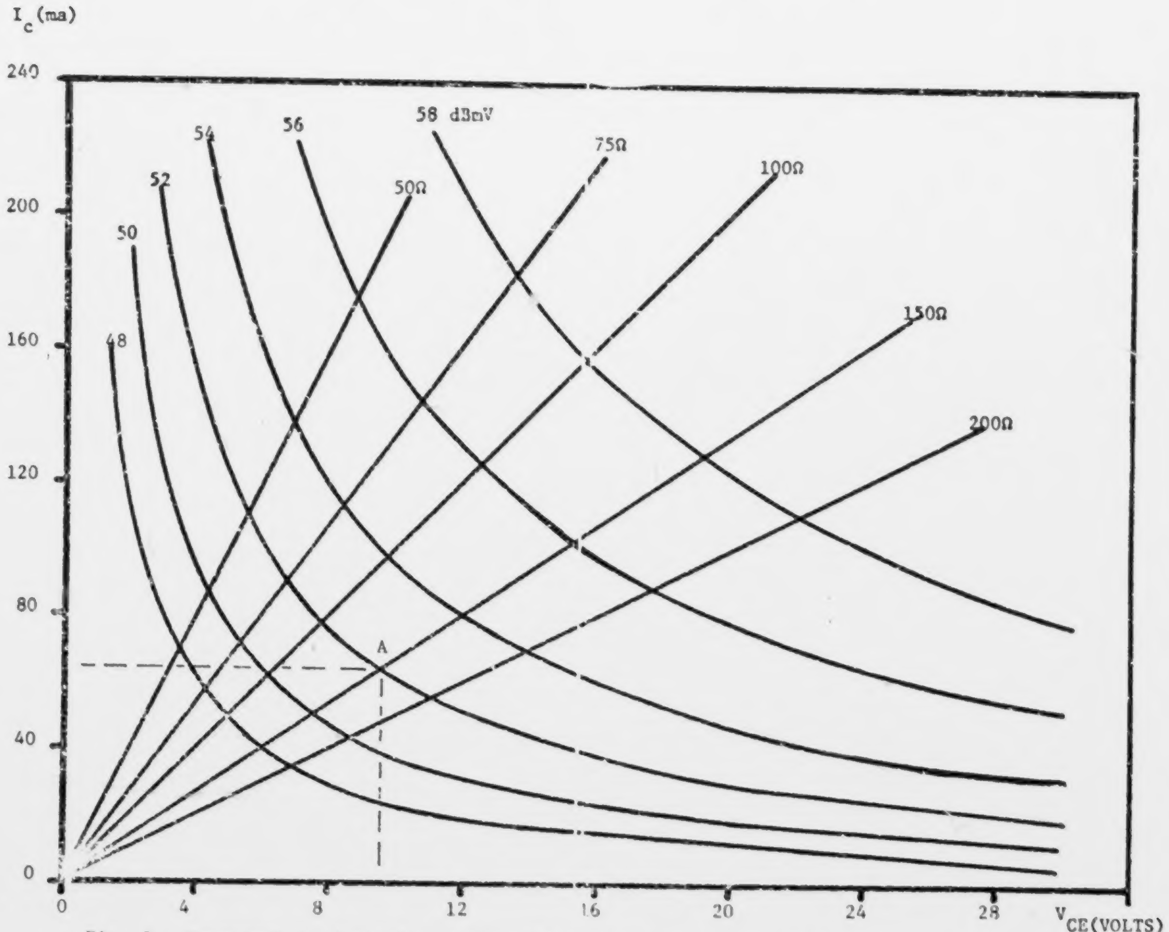


Fig. 3. Nomograph to determine minimum bias point for a given collector load impedance and 12 channel flat operating level.

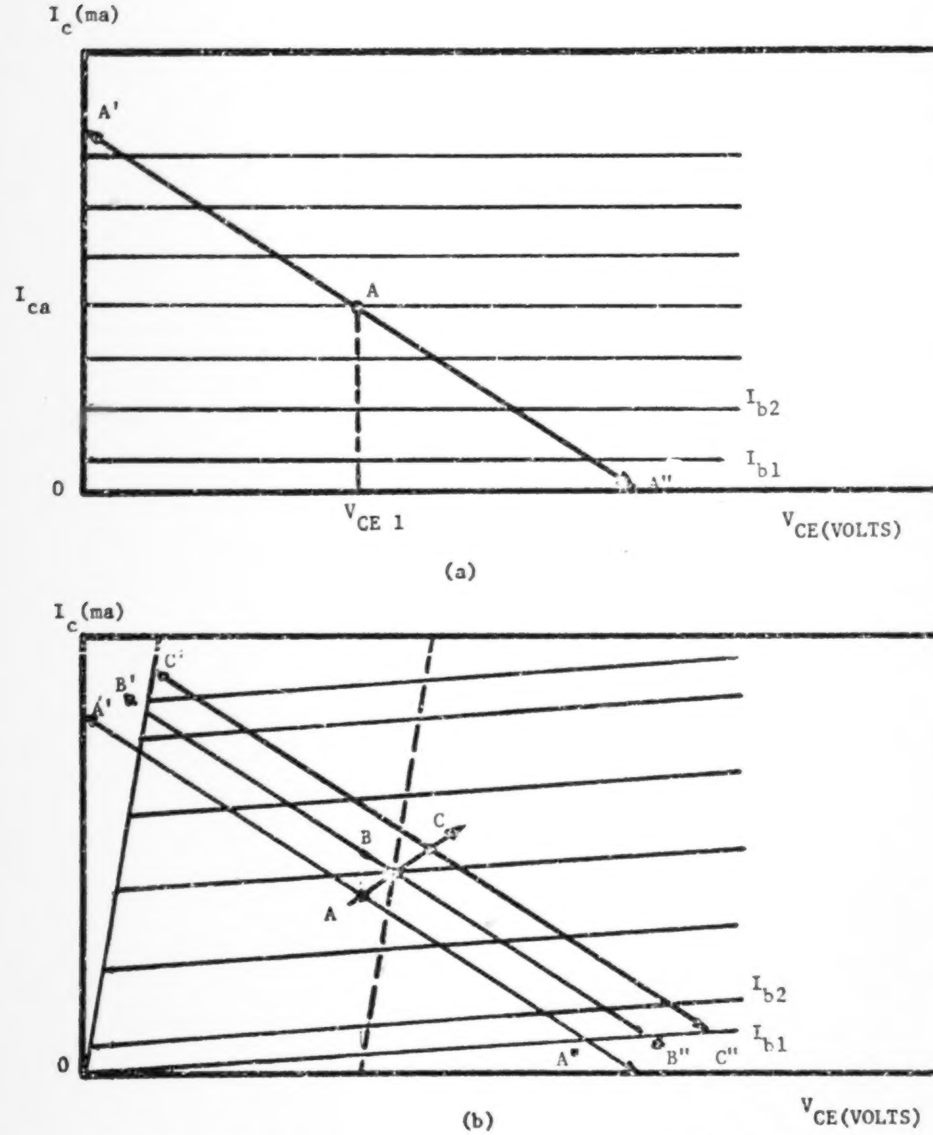

I_c (ma)
A'
I_ca
A
I_b2
I_b1
0
A''
V_CE 1
V_CE (VOLTS)
(a)
I_c (ma)
C'
B'
A'
B
C
A
I_b2
I_b1
0
A''
B''
C''
(b)
V_CE (VOLTS)

Fig. 4. (a) Over idealized device curves with 150Ω loadline for + 50 dBmV, 12 channel operating.
(b) Idealized curves showing required bias point shift to prevent waveform clipping.

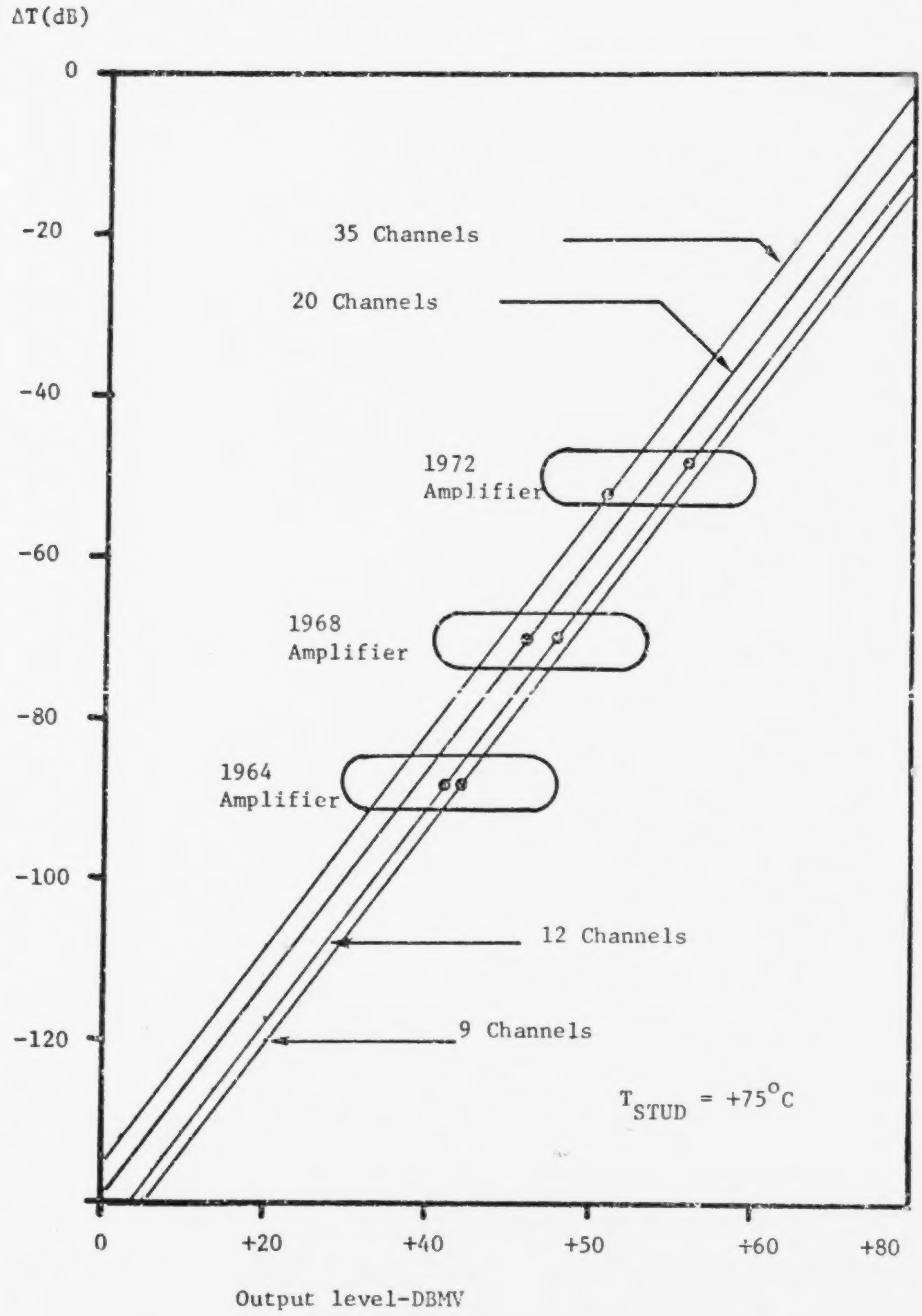


Fig. 5. Thermal modulation of device temperature

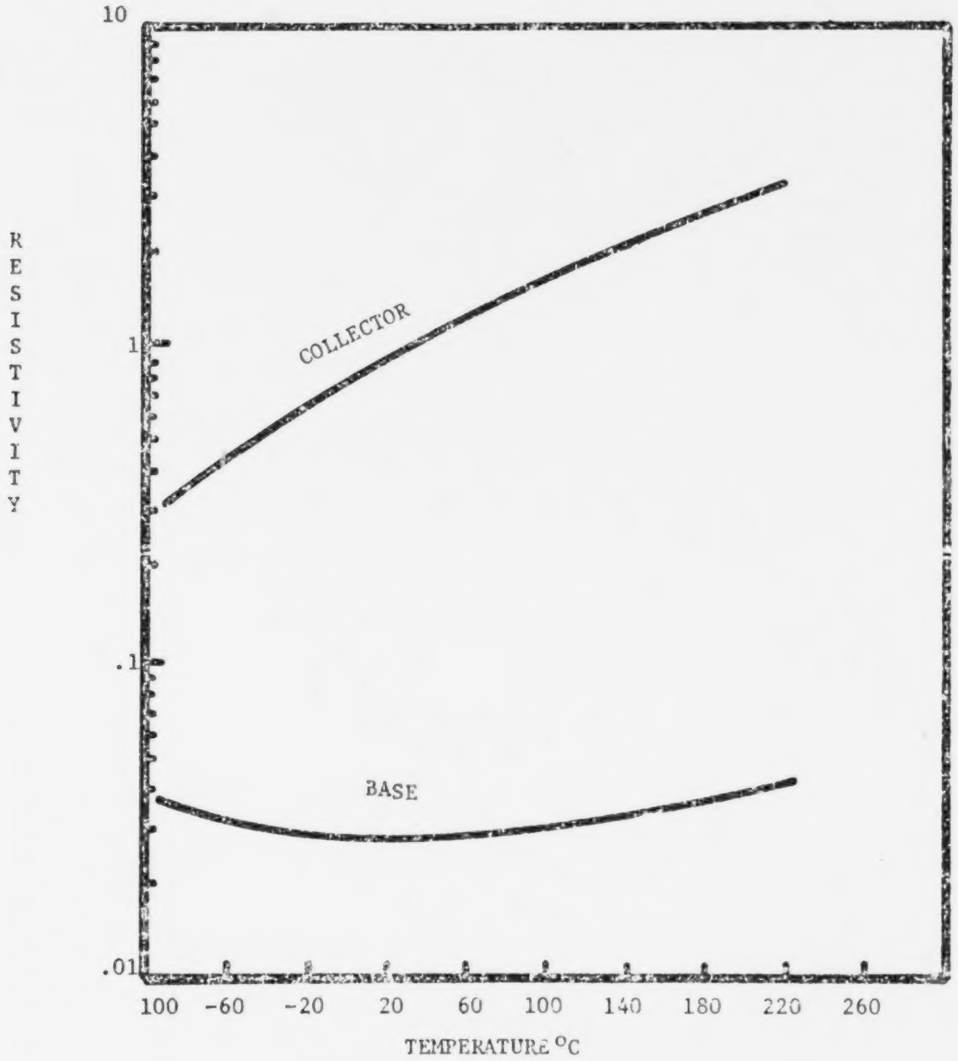


Fig. 6. Resistivity versus temperature for collector and base material.

532

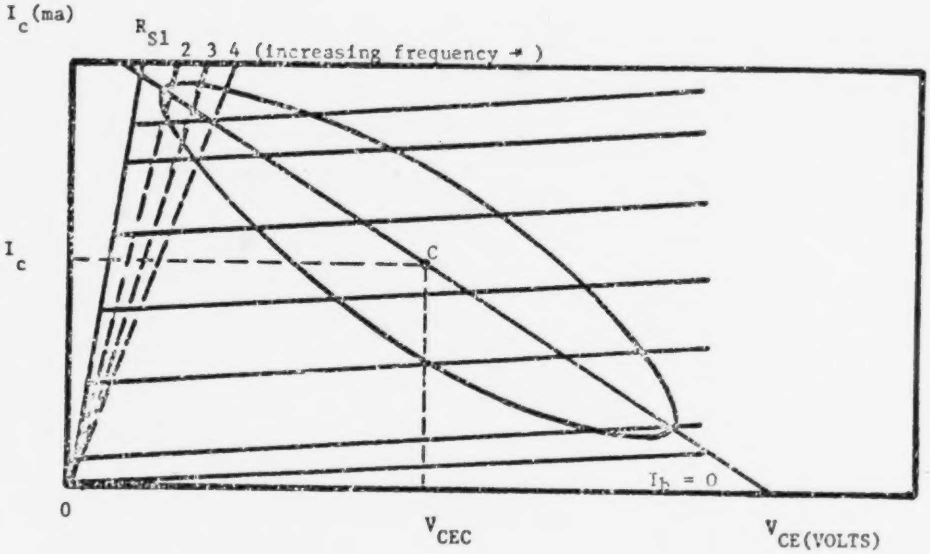


Fig. 7a. Idealized device curves with increasing saturation resistance as a function of frequency and a reactive loading.

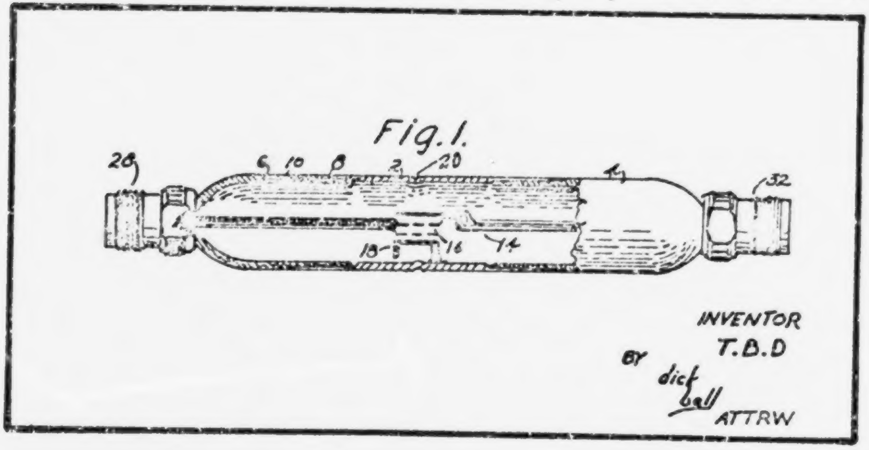


Fig. 1.
28
6
10
8
2
20
4
32
18
16
14
INVENTOR
T.B.D
BY
dick bell
ATTRW

Fig. 7b. Over-idealized device that could produce the curves in Fig. 4a.

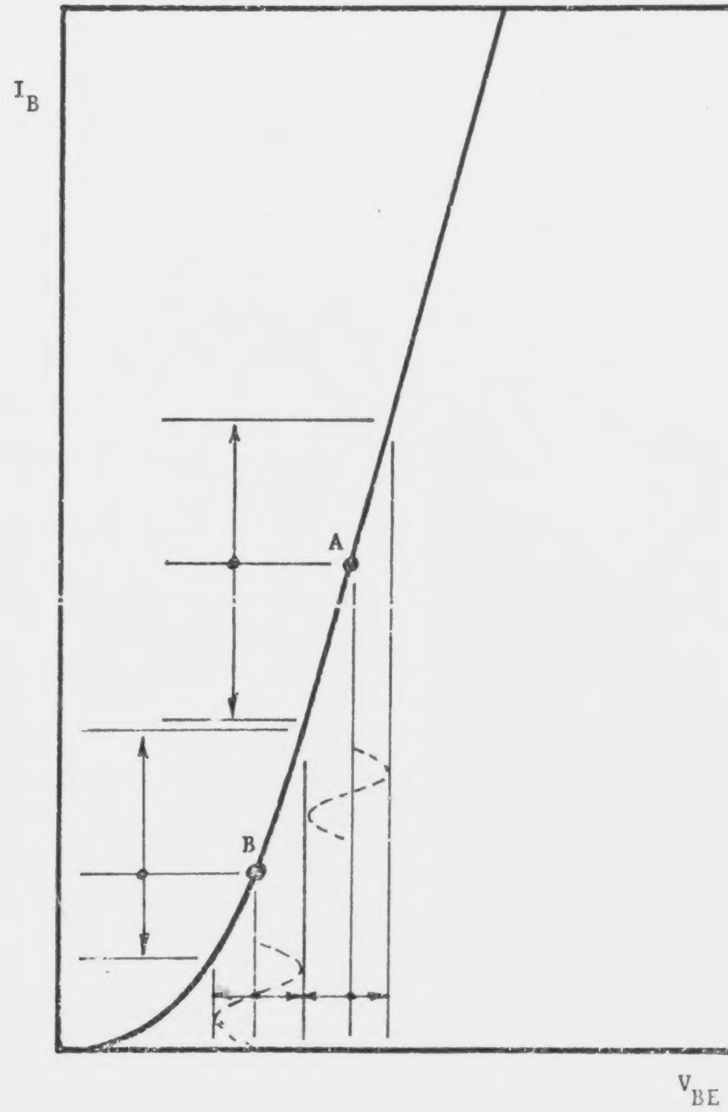


Fig. 8. Base-emitter diode characteristic.

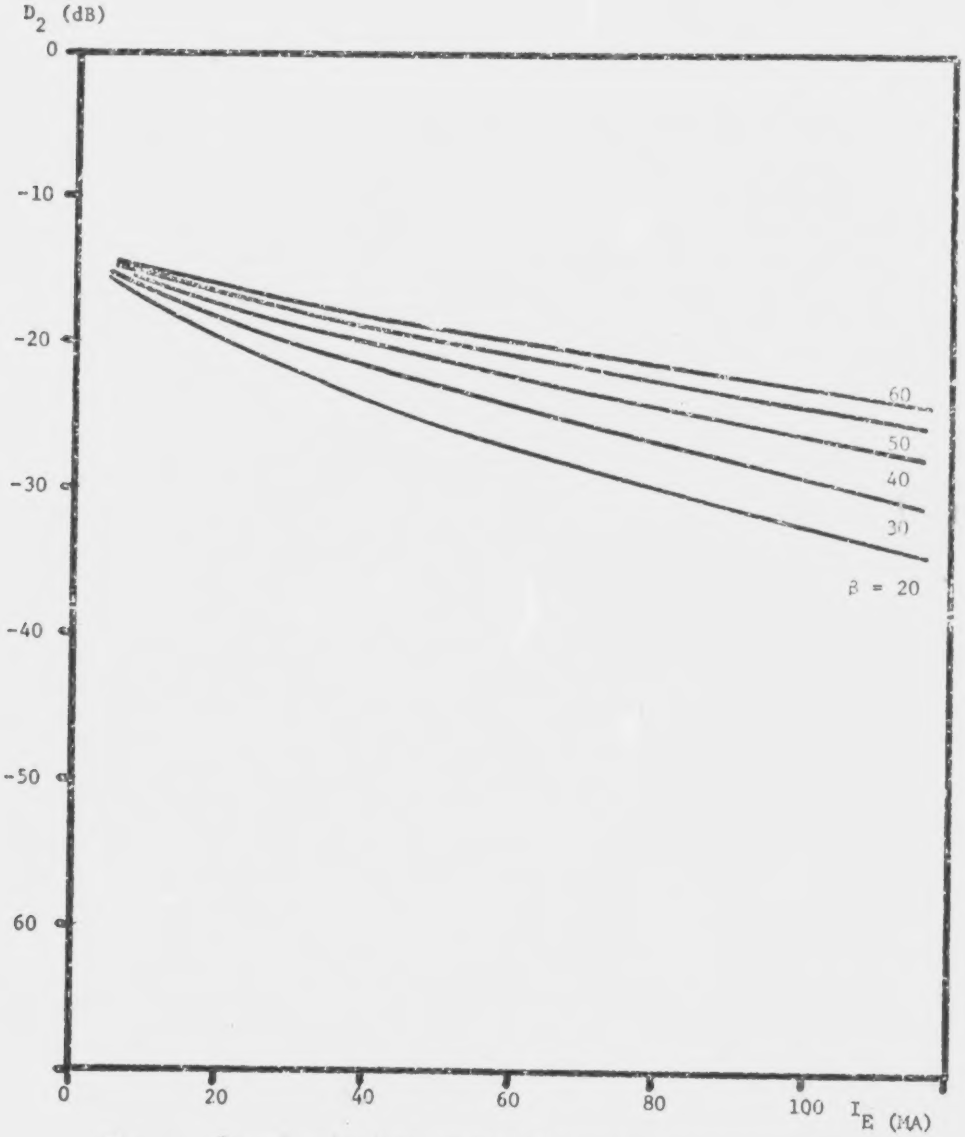


Fig. 9. Second order base-emitter distortion characteristics for Rs = 10Ω

535

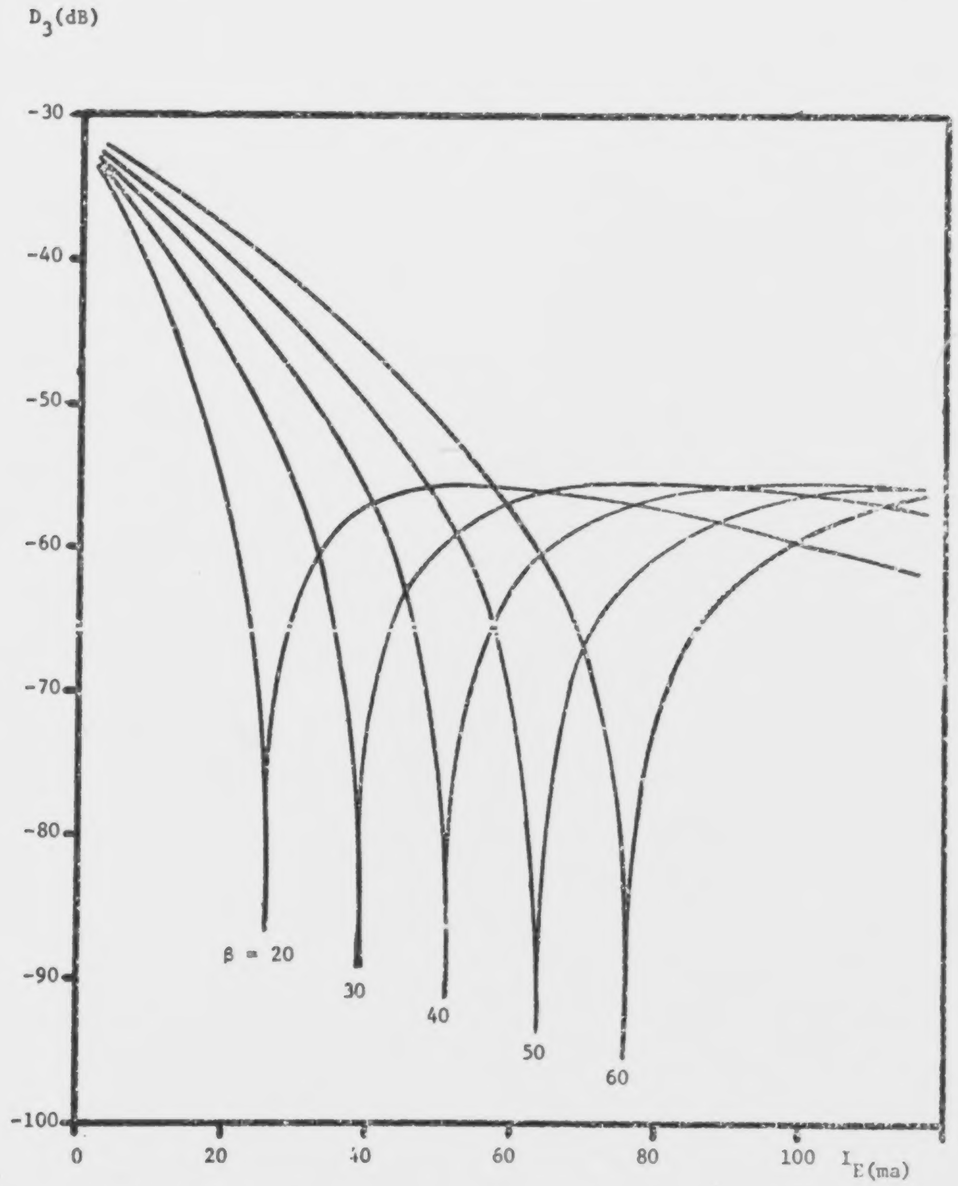


Fig. 10. Third order base-emitter distortion characteristics for Rs = 10Ω

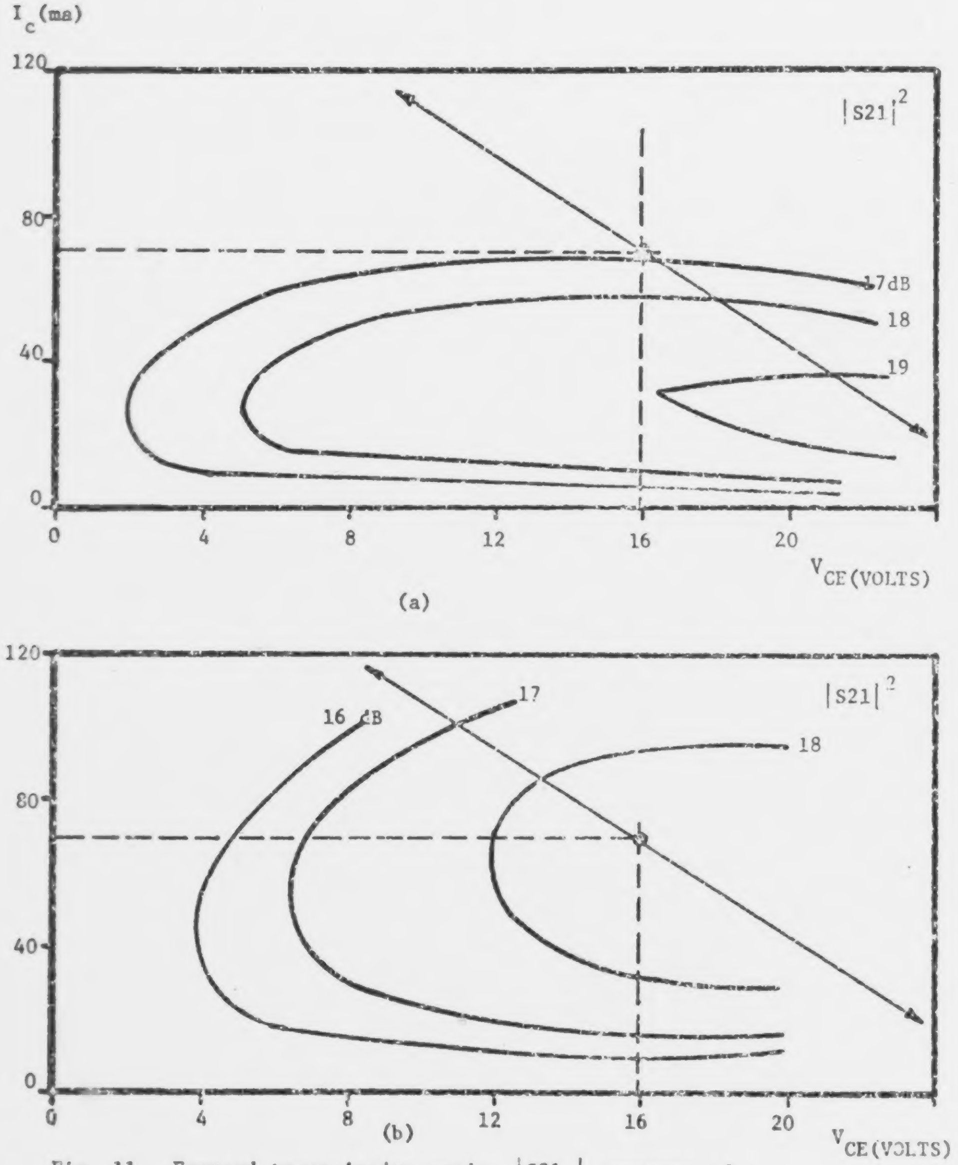


Fig. 11. Forward transmission ratio $|S21|$ contours of a
(a) Low-noise small signal microwave transistor (MATV front end)
(b) Medium power microwave transistor (1 watt, 2 GHz class C)

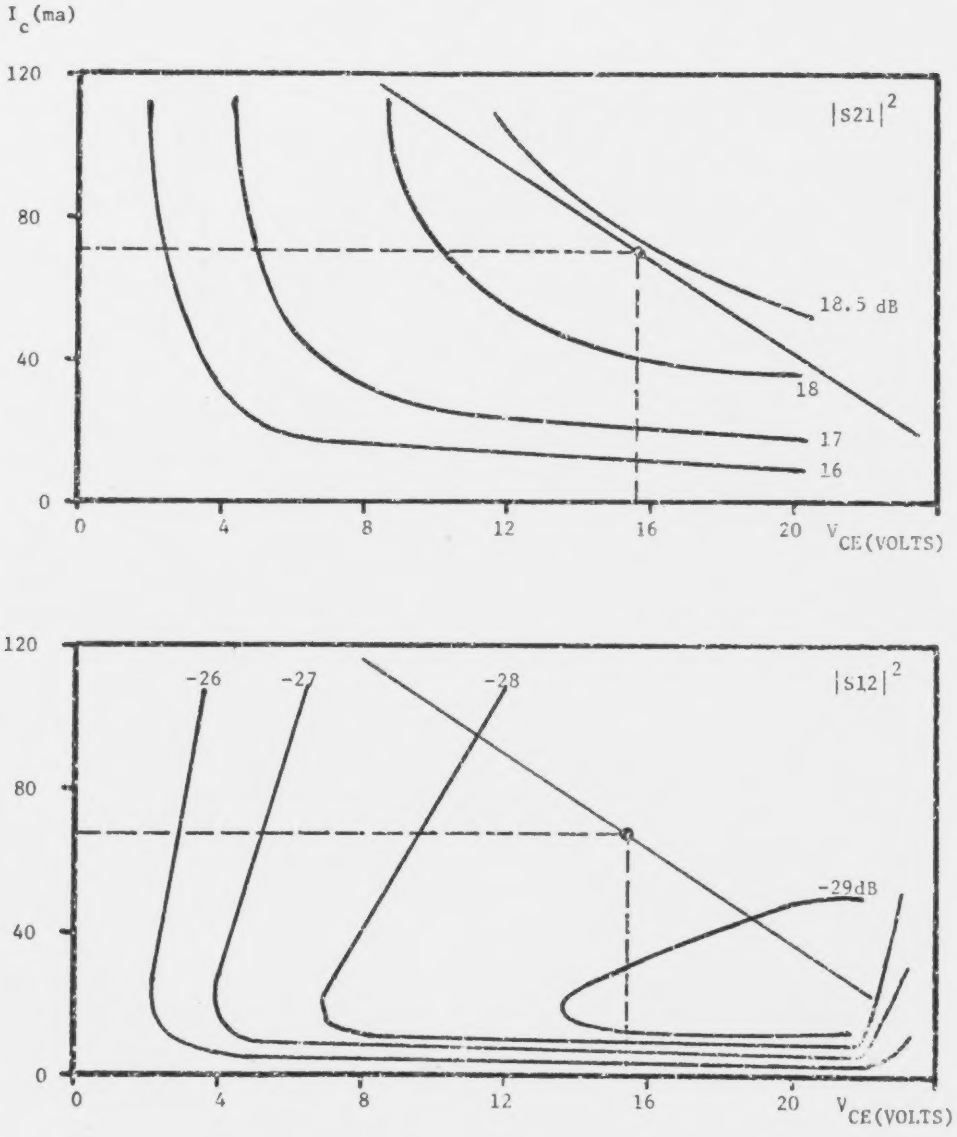
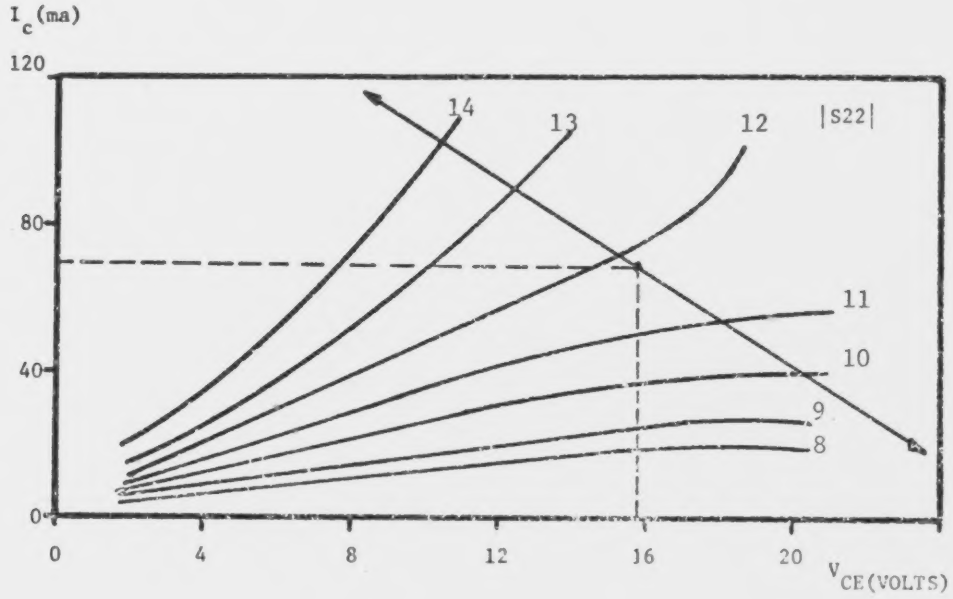


Fig. 12. Forward and reverse S-parameter contours at 250 MHz



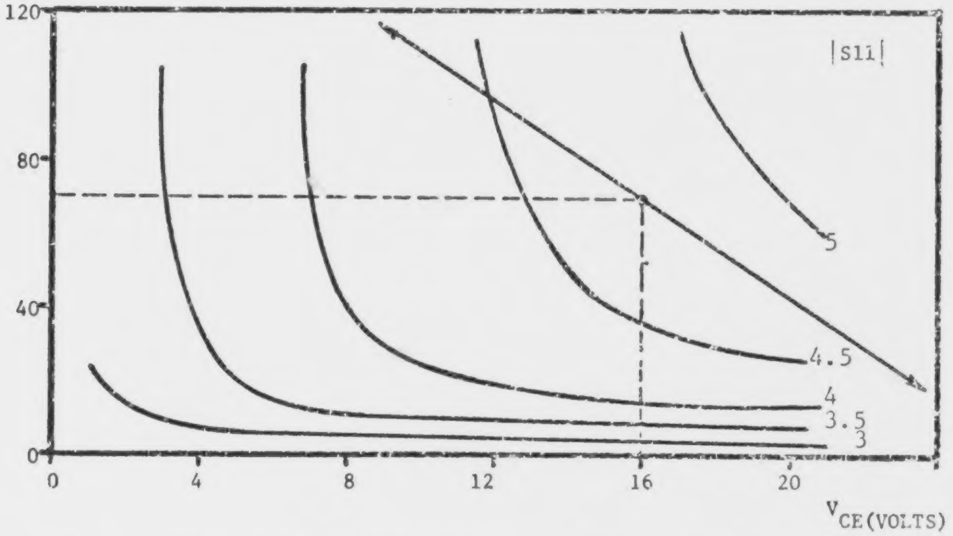
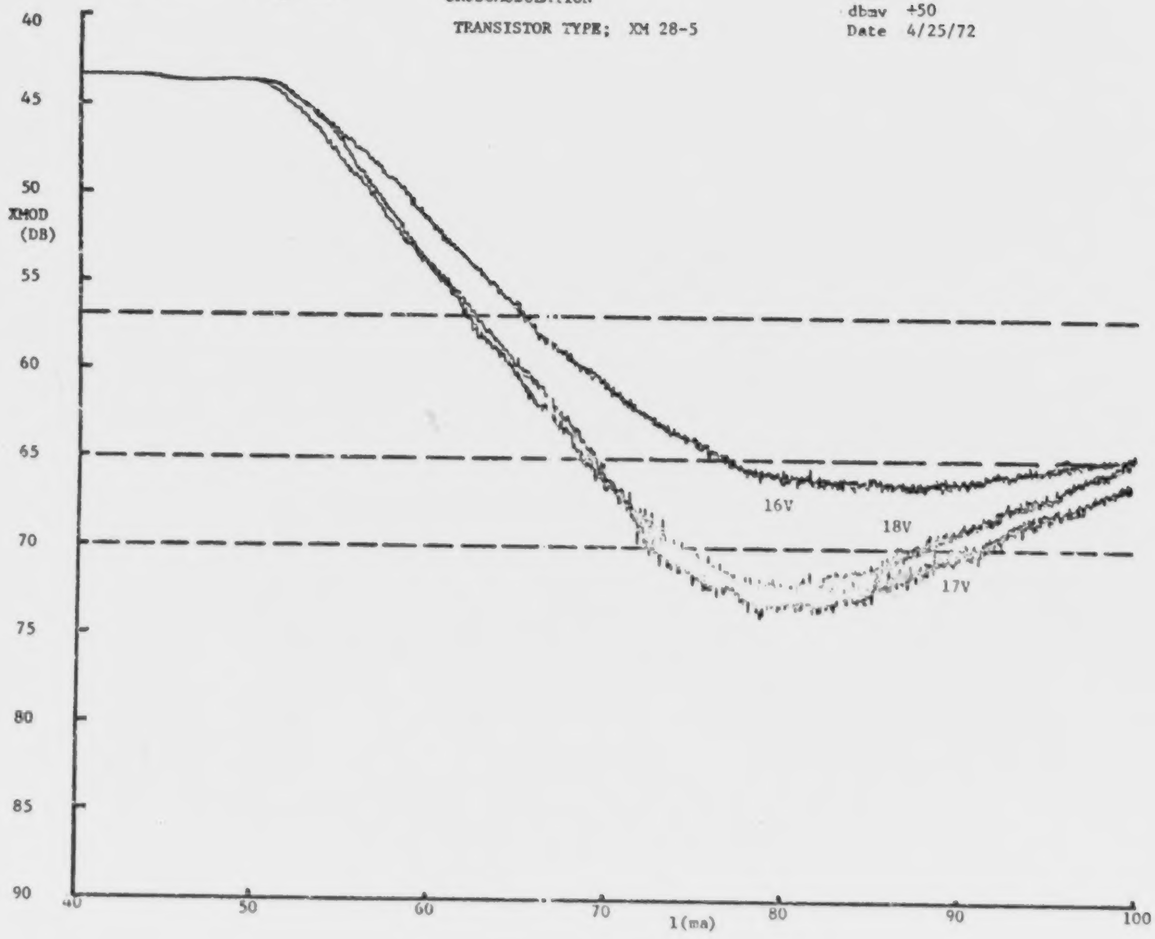


Fig. 13. Output and input S-parameters contours at 250 MHz.



TRW LAB 1 Fig. 14.

CROSSMODULATION
TRANSISTOR TYPE; XM 28-5

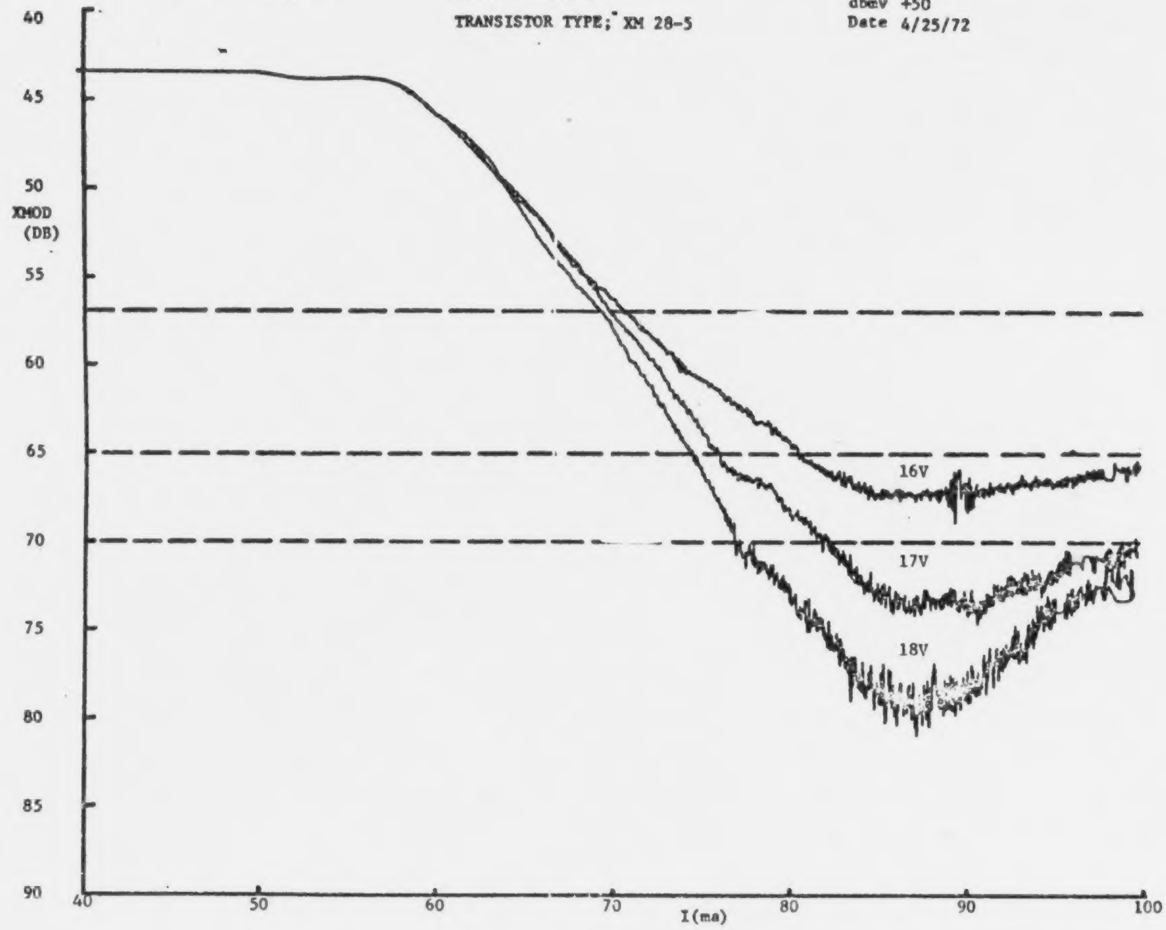
CHAN 2
dbmv +50
Date 4/25/72

540

TRW LAB 1 Fig. 15. CROSSMODULA'.ION

TRANSISTOR TYPE; XM 28-5

CHAN 13
dbmv +50
Date 4/25/72

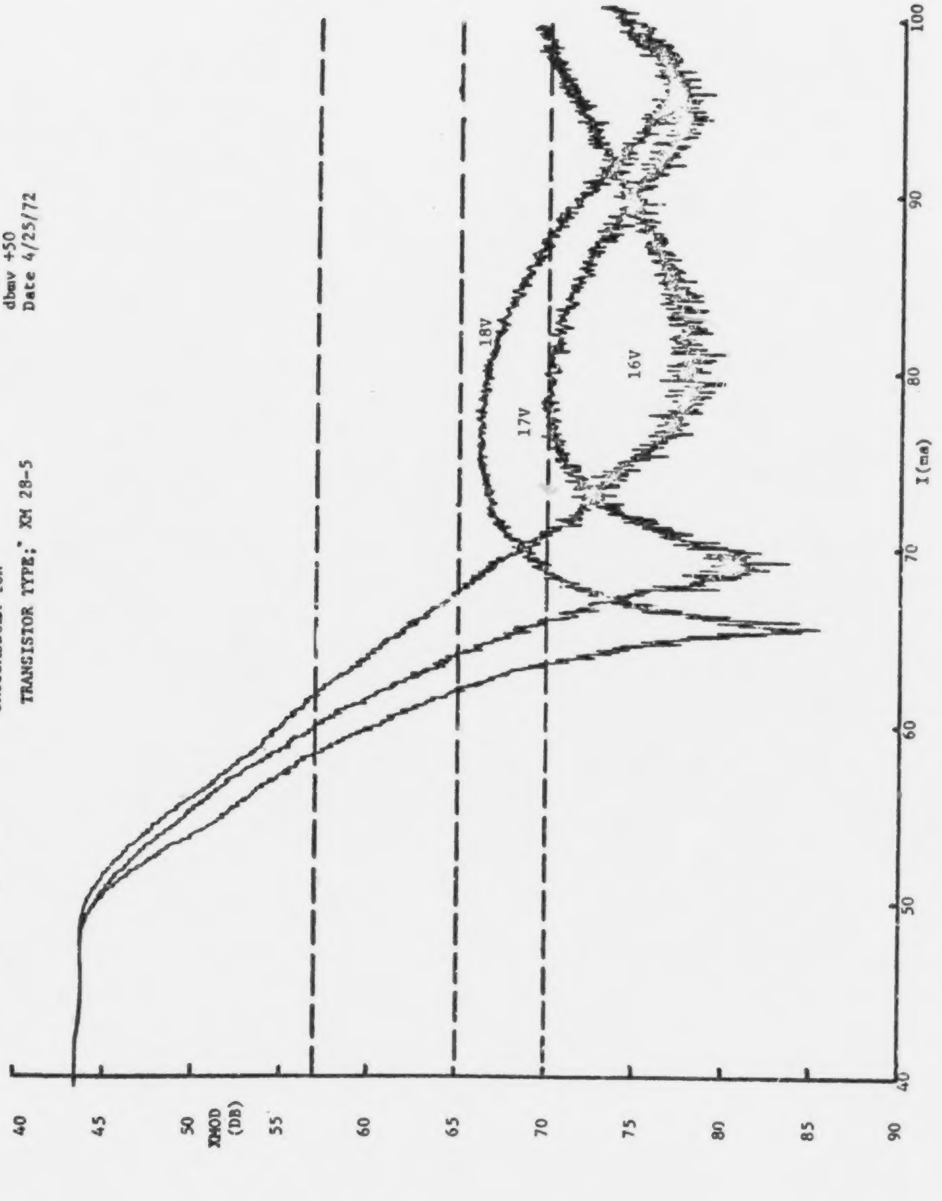


TRW LAB 1 Fig. 16.

CROSSMODULA'TON

TRANSISTOR TYPE;' XM 28-5

CHAN 2
dbmv +50
Date 4/25/72



542

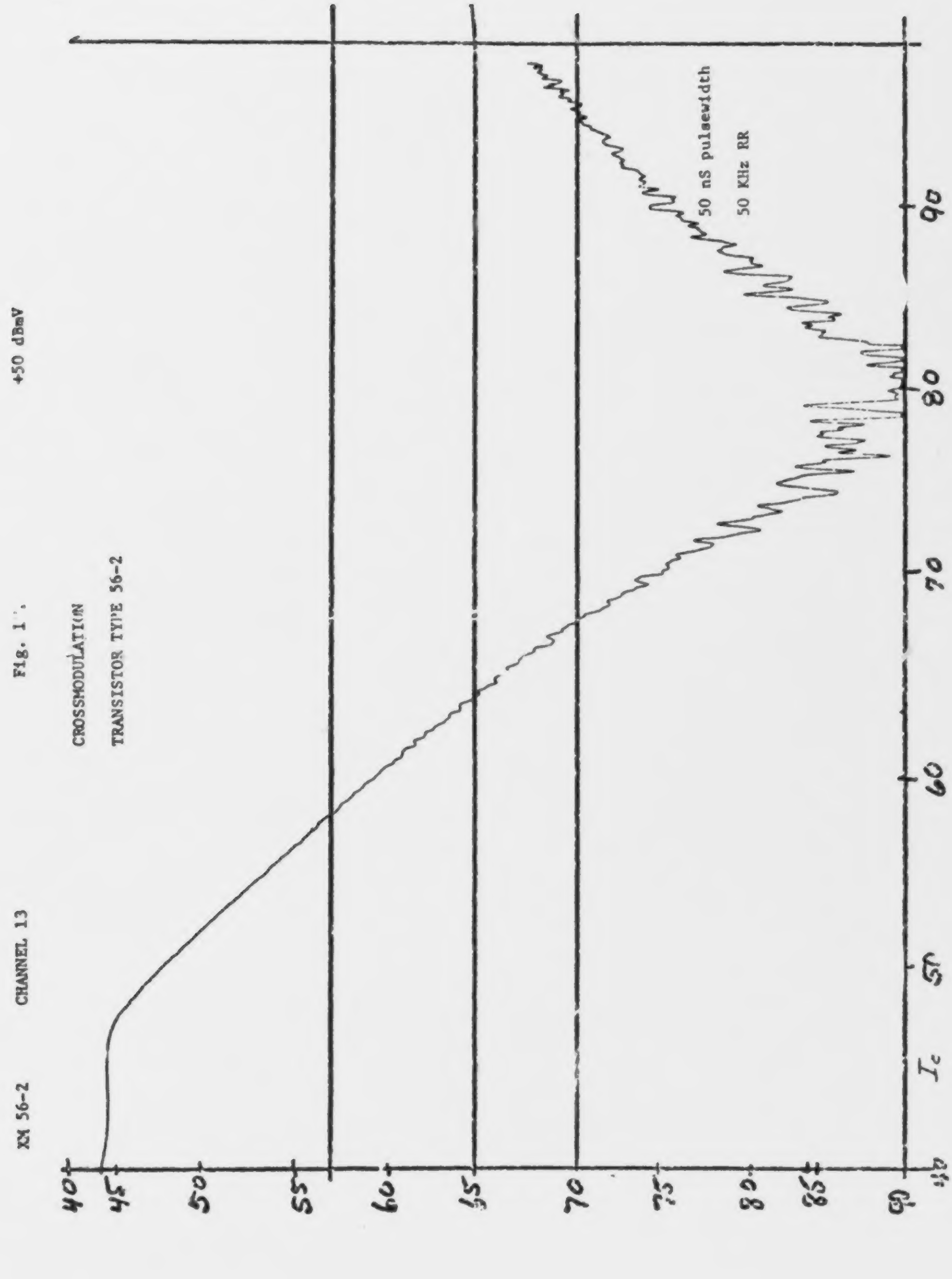


Fig. 1[illegible].

CROSSMODULATION

TRANSISTOR TYPE 56-2

XM 56-2

CHANNEL 13

+50 dBmV

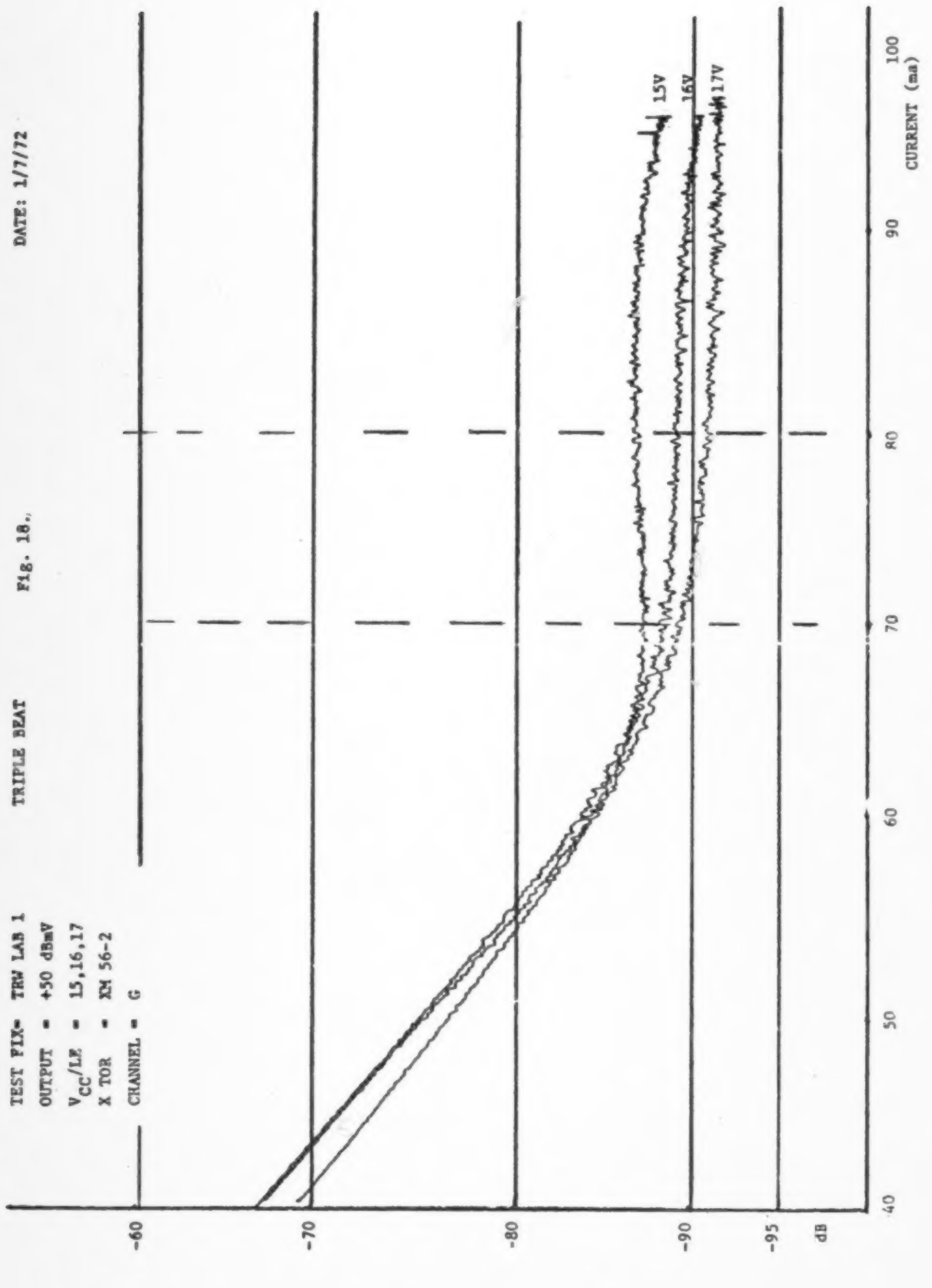
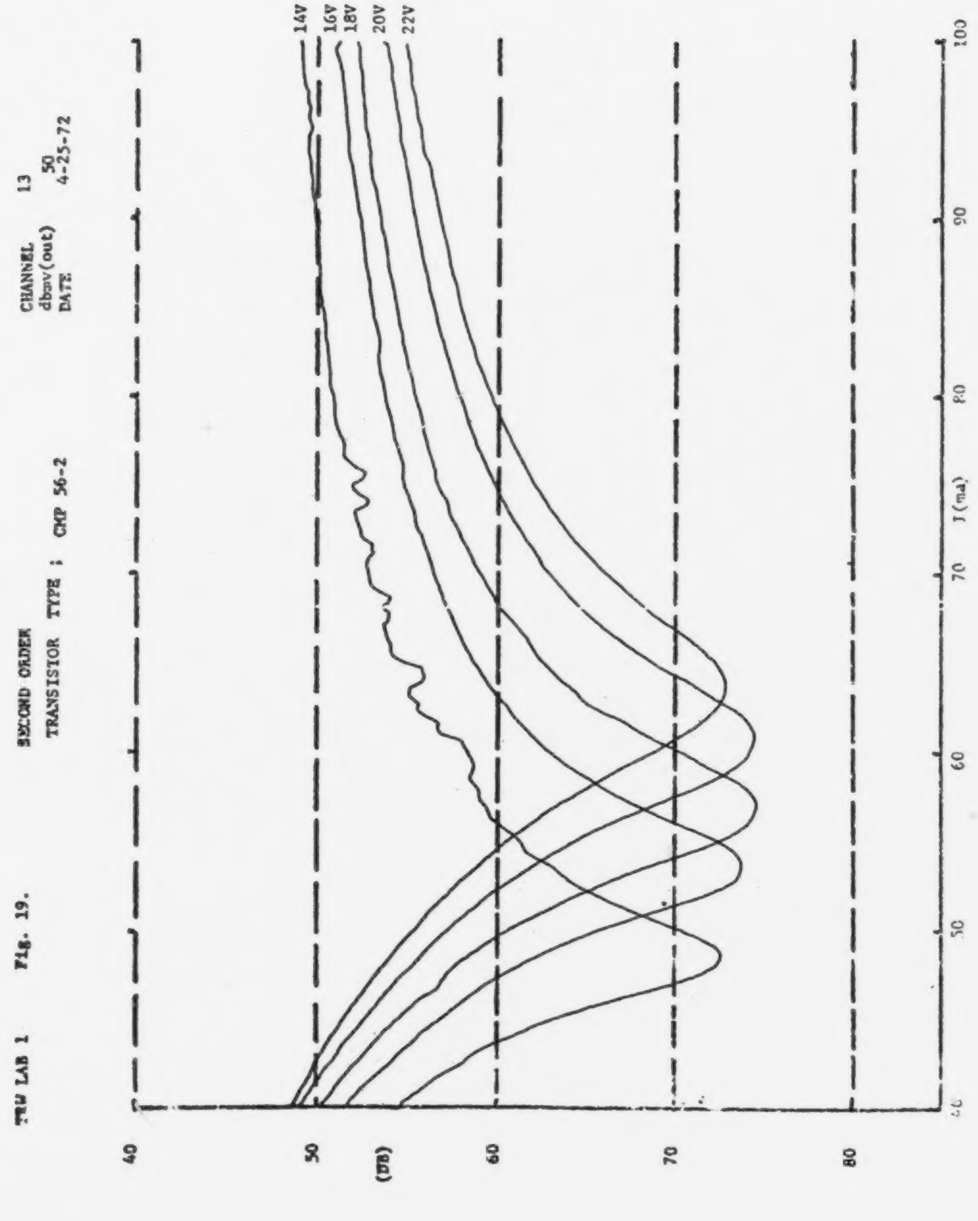

TEST FIX- TRW LAB 1
OUTPUT = +50 dBmV
V_{CC}/LE = 15,16,17
X TOR = XM 56-2
CHANNEL = G
TRIPLE BEAT
DATE: 1/7/72
15V
16V
17V
-60
-70
-80
-90
-95
dB
40
50
60
70
80
90
100
CURRENT (ma)

Fig. 18.

544

TRW LAB 1 Fig. 19.

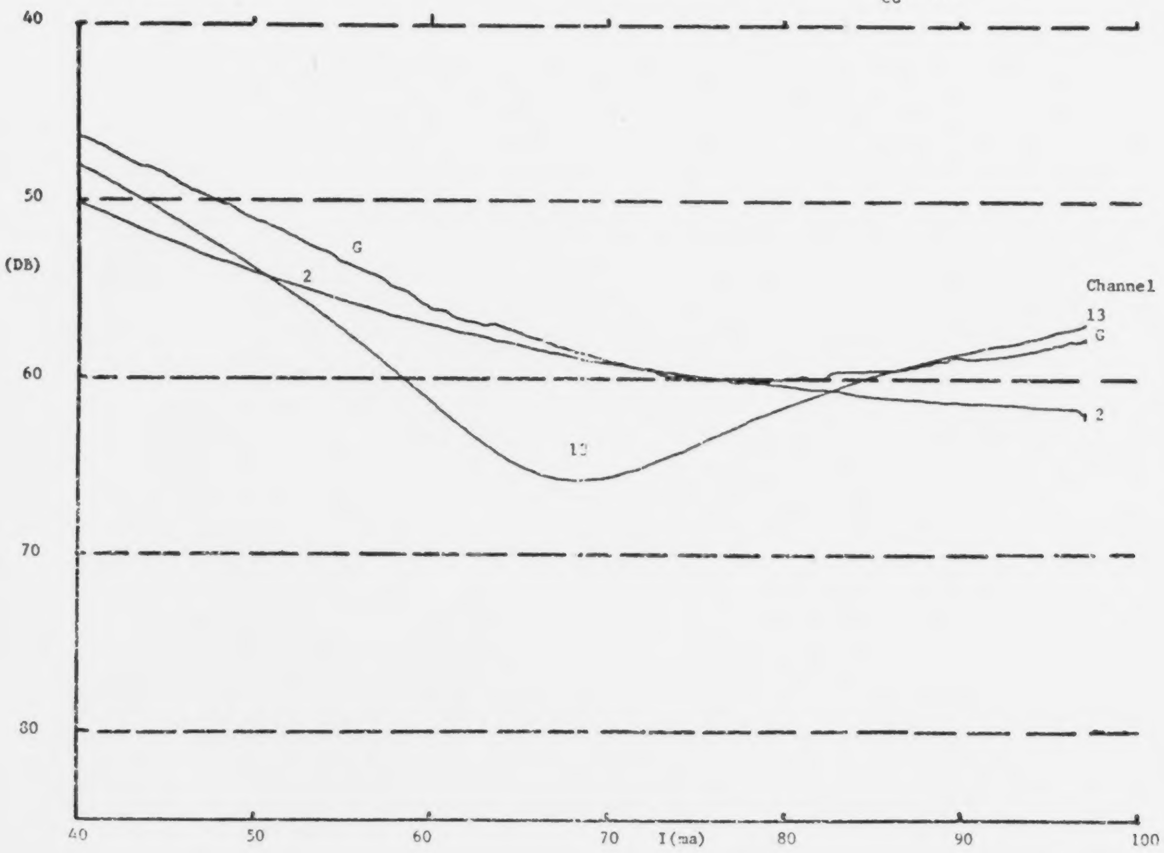


545

TRW LAB 1 Fig. 20.

SECOND ORDER
TRANSISTOR TYPE ; XM 28-5

CHANNEL
dbmv(out) +50
DATE
V_{CC} = 16V



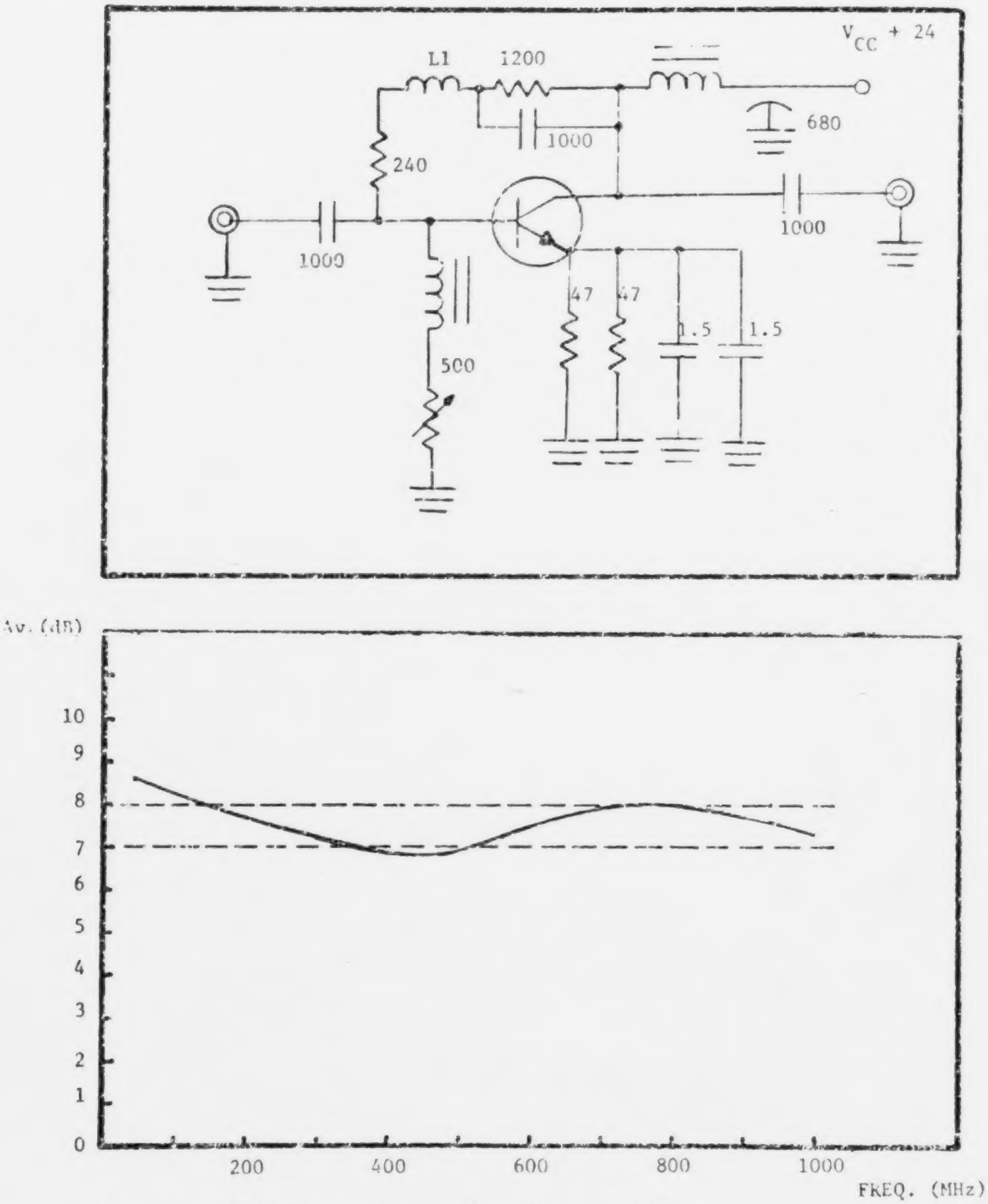

L1
1200
V_CC + 24
680
1000
240
1000
1000
47
47
1.5
1.5
500
Av. (dB)
10
9
8
7
6
5
4
3
2
1
0
200
400
600
800
1000
FREQ. (MHz)

Fig. 21. a) Single-stage transformerless amplifier
b) Voltage gain versus frequency

HIGHLIGHTS
TECHNICAL SESSION

UNDERGROUND ENGINEERING

Chairman

Charles Henry
Badger CATV
Iron Mountain, Michigan

Speakers

Robert J. Hoffman
American Public Works Association
Chicago, Illinois

Theodore J. Swanson
Cypress Communications
Los Angeles, California

J. Robert Bird
Cypress Communications
Los Angeles, California

Dr. Richard Barone
Texas Instruments Inc.
Attleboro, Massachusetts

George R. McGrory
Burnup & Sims
West Palm Beach, Florida

Gene Moon
Community Cablevision Company
Newport Beach, California

Reporter

Richard C. Schneider
Community Television Systems of Wyoming
Casper, Wyoming

1. "Municipal Codes and Regulations" - Robert J. Hoffman

Mr. Hoffman explored some of the municipal regulations that the cable industry is expected to encounter, especially as they pertain to underground engineering, and explained the necessity of such regulations from the municipalities' point of view. Forty-nine percent of all public power systems have adopted policies of undergrounding distribution facilities in all new residential subdivisions, and telephone companies have programs to convert existing aerial facilities to underground. As most utilities are located in street rights of way, it follows that the undergrounding of these facilities will result in a number of conflicts with respect to the cutting of pavement for installation and maintenance of underground electric distribution and communication systems. In addition, the accidental digup of underground utility lines is a problem that plagues many communities and utility companies. Mr. Hoffman urged all cable operators to join with other utility companies and municipal departments and the other utility coordinating committees that are being formed throughout the country in order to coordinate their efforts for their common good.

2. "Highlights - Underground Construction Techniques" - Theodore J. Swanson & J. Robert Bird

Mr. Swanson opened his talk by stating, "...if you don't have to go underground with the cable plants, don't do it..." It can be an extremely expensive venture, especially in the major metropolitan areas. Some of the areas of concern are: developing the right-of-way easement; cost of concrete, pavement cutting or trenching; labor and material factors; maintaining onsite supervision when facilities are being placed in joint trenches; cost of coverup, blacktopping, etc.

Experience has shown that a certain amount of civil engineering practice is necessary in order to properly design, sketch, and engineer an underground facility in the highly developed areas.

Of the materials available today, Cyprus advocates that the construction of most of the underground cable be buried plants with conduit. It provides the convenience of future maintenance and refurbishing. Additionally, if placed relevant to homes in new developments and tracts, there is a potential of additional future revenue. As an example, in the late 1800's, New York City franchised various entrepreneurs to place conduit within the streets of New York. Today, these conduits and rights of way are highly overburdened with communications facilities. It is advisable to get the conduit facilities installed at the time the joint trench is open, thus allowing the installation of cable and electronic facilities when the tract is fully developed and when cable TV would be a financially successful endeavor. Additionally, early installation of conduit saves the expense of the installation later without the complication of street borings and enclosures of private property refencing and landscaping. However, with the constant state of change, the cable plants buried five years ago will not handle the 20-channel, two-way transmission requirements that our industry is presently recommending. Mr. Swanson felt that the advantage of having the capability of being able to remove and refurbish today's cable facilities will far outweigh the cost factor in having to completely reconstruct for the future technological changes. Three areas mentioned where direct burial of cable television facilities should be considered were rural areas, existing tracts or developments where economics of cable operations prohibit the placement of conduit type facilities, and undeveloped areas where extensive streets and sidewalks have not yet been placed.

The type of conduit material was discussed--polyethylene vs. polyvinyl chloride conduit (PVC). Polyethylene comes in 300' sections and is a soft and semiflexible material. It is easy to place in a trench, can be bent to make corners and curves without special elbows and plumbing, is generally cheaper and quicker to install. Its disadvantages are: it is hard to handle and store, bulky and difficult to ship, cannot be glued or sealed and is easily collapsed if thin-walled. PVC comes in shorter lengths, is easily shipped and stored. It is easily installed with special solvents allowing effective seals, can be manufactured with preformed splices and bends for short radii. Its disadvantages are: it costs 20 to 30 percent more than polyethylene, requires more labor to install, requires consistent chemical properties and wall thickness because of its being easily shattered by rocks and sharp blows of the workers' tools.

When conduit is installed prior to the installation of the cable and electronic facilities, it is necessary to be able to trace the conduit. It is advisable to install a pull wire or pull rope which will enable later pulling of the coax. Its most important aspect is that one can attach a signal generator to the wire and with the use of of a pipe tracer or metal detector, one can trace the conduit routing underground. This is helpful in finding conduit breaks.

Mr. Bird covered some of the problems of underground installation--the difficulty in obtaining pole contracts and, in some cases, the requirements in franchises and pole contracts. Mr. Bird covered the two common methods of installing buried cable--plowing and trenching, and discussed the technique for splicing after installation if it is inevitable that the cable will be cut and a splice required.

Another aspect of an underground plant is the importance of accurate maps and record keeping. Maps should denote the depth of the cables, the distances between amplifiers and other equipment, and their exact locations in respect to permanent landmarks. The records should include accurate flow charts on each amplifier, equalization methods, cable characteristics, and a maintenance record on all amplifiers.

3. "Simulated Environmental Aging of CATV Cable" - Dr. Richard Barone

Dr. Barone introduced his talk by pointing out the continual technological advancement of the CATV industry with examples. Many of the improvements were directly attributable to improvement in the cable materials or the manufacturing method involved in making the cable. Tests were made on seamless aluminum shielded CATV cable with a foamed polyethylene dielectric. Residual compressive stresses in the cable were measured using the parameter of aluminum shield removal force. A series of time-temperature exposures were run on one-half inch diameter cable after which aluminum shield removal force measurements were made on specimens having a contact length of two and one-half inches. The rapid rate of decay at times and temperatures easily encountered in the field suggests that high stresses induced by manufacturers in order to minimize moisture absorption may exist for only a short time since environmental conditions may anneal out the residual stresses.

Another fact of interest was that the center conductor/dielectric bond is chemical in nature and even stronger than the dielectric itself, whereas, the aluminum shield/dielectric bond is strictly mechanical in nature.

4. "Underground Costs and Installation Trade-Offs" - George R. McGrory

Mr. McGrory pointed out some of the reasons why underground installations are increasing in the communication industry. In addition the local governmental agencies are beginning to insist that all new construction be placed underground. Some of the disadvantages of changing from aerial to underground were enumerated--locating other underground facilities, removing and restoring sod, opening trenches and installing cable, installing electronic devices.

Labor costs were explored for a typical normal installation and installation with conduit. Installation with conduit is much more expensive; however, considering the changes that are going to take place in the future--increased bandwidth capabilities, system redesign for dual plant capacity, and increased labor and maintenance costs--planning and scheduling will help save many dollars

5. "Reliability and Maintenance of Total Underground Systems" - Eugene R. Moon

Quality components do not necessarily equate to a quality system; but to build a reliable system, one must begin with quality components.

Conduit in underground construction is the most important single item next to waterproofing. Your system should be planned so as to have space for future expansion, for example, two-way transmissions probably will require more than one cable in the conduits. Trunk cable and feeder cable in separate conduits allows for possible replacement with minimum of down time; damming of conduits in flush vaults is very important; and the use of duct tape (silver tape) when installing conduits in vaults is cheaper than cleaning conduits later.

Concrete vaults are common in underground systems. The size, location, and lids are important considerations when planning actual construction. Size is most important because minimum cable bending radius dictates the size, not price. Location is next in importance. Watch for drainage routes that may leave a vault constantly full of water. Location dictates the type of lid required. The steel fishplate lids in some cases will save money due to constant breakage.

Pedestals above ground are the least expensive protection for active and passive components, but also have some pitfalls. The most common problem is condensation. Adequate air space between the ground level and the base of the pedestal will ensure that practically no condensation takes place. In addition, for continued protection, heat shrink sleeves (or tape) and a coating of liquid neoprene may be used. Don't just think dry construction but practice dry construction.

Waterproofing equipment enclosures is the single most important item relating to reliability and maintenance of total underground systems. Mr. Moon pointed out that, as experienced constructors, they rely heavily upon good pedestals and hermetically-sealed enclosures. The additional cost of the enclosure and labor to install are quickly recaptured by lower maintenance expenses.

Commercial power outages are fewer in areas where all utilities are underground.

In a discussion after Mr. Moon's presentation, a suggestion was made that the CATV industry adopt a standard color for the CATV conduit. Other underground facilities also could be recognized by standard colors.

MUNICIPAL CODES AND REGULATIONS

by

Robert J. Hoffman

Assistant Director of Research

American Public Works Association

Chicago, Illinois

It has often been said that nothing is certain except death and taxes. One might add a third certainty -- governmental regulation. Whether we like it or not, governments do regulate many aspects of our business activities and even our personal conduct. In all liklihood, governmental regulation will increase, rather than diminish, as our society continues to urbanize and become increasingly interdependent.

Most of us have mixed feelings about regulations -- we object to them when they restrict us, but we can readily appreciate the need to control the other guy. This is as true of governmental officials as it is of private citizens and businesses. We become highly indignant if a zoning ordinance prohibits us from building an 8 foot high fence in our own backyard, but are quite relieved when it prevents our next door neighbor from opening an auto repair shop in his garage as a home occupation. There are obviously different points of view. This afternoon I would like to explore with you some of the municipal regulations that you can expect to encounter, especially as they pertain to underground engineering, and try to explain from the municipality's point of view the necessity of such regulations.

I know that there is much controversy and uncertainty surrounding the regulation of your industry at this time. At least three levels of government, federal, state, and local claim jurisdiction. I don't know how this will finally be resolved, but I am willing to bet that municipalities will retain at least some jurisdiction, particularly as it pertains to the use of municipal street rights-of-way for the location of cable television facilities.

Municipal Franchises

The franchise agreement granting an operator the right to provide cable television service in the municipality and setting forth the conditions under which the franchise is granted is the basic agreement between the operator and the municipality. This agreement will almost always carry a provision requiring the operator to comply with all applicable municipal ordinances, regulations, and standards. The franchise may also incorporate by reference the provisions of such national codes as the National Electrical Safety Code for work in the public right-of-way, the National Electrical Code for work on private property and inside buildings, and others as well as municipal ordinances relating to street openings and traffic control. The Occupational Safety and Health Act of 1970 is another regulation that will affect your operations, however, this is being administered at the state or national level rather than at the municipal level.

The franchise may be a very comprehensive, restrictive, and tightly worded document, or it may be very brief and less restrictive. As you know, municipalities until recently had no experience with cable television, and the franchises they granted reflected this fact. In the beginning it seems that most municipalities were concerned principally with the revenue to be realized from the franchise and neglected some other important considerations. To provide some guidance, the National Institute of Municipal Law Officers in 1969 issued a model ordinance for the granting of non-exclusive community television franchises, which contains clauses concerning: compliance with applicable laws and ordinances, company liability, service standards, company rules, condition of street occupancy, preferential or discriminatory practices, extension policies, transfer of franchise rights, city rights in the franchise, payments to the city, rates, records and reports, term of the franchise and penalties, among others. I suspect that you are now finding municipalities becoming a little more sophisticated and perhaps demanding, in their approach to the writing of franchise agreements. I think that the franchises that you will be looking at soon will be concerned additionally with the capability of the system especially concerning: two-way communications; the number of channels required to be provided; the allocation of channels for different uses including free, dedicated non-commercial public access channel availability, educational channels, and municipal channels; the type of service to be provided such as meter reading and alarm systems, and communication and control capabilities such as information retrieval; the identification of priority groups to be served; and provision of production facilities and staff support for public programming among other requirements.

Street Opening Regulations

Apart from the terms of the franchise agreement itself, the municipal regulations which will have the greatest effect on your operation will probably be the street opening regulations. You may not have come across many of these yet since so much of your existing plant is aerial construction. However, it is clear, or ought to be clear to everyone, that the trend toward the undergrounding of electrical supply and communication facilities will continue. In 1971 approximately 88% of the new building sites served by the various telephone companies was via underground construction and many telephone companies have programs to convert existing aerial facilities to underground. Forty-nine percent of all public power systems have adopted policies of undergrounding distribution facilities in all new residential subdivisions. Investor-owned electric utilities are also undergrounding their new installations and converting existing aerial plants. In most cases undergrounding is being done voluntarily but utility commissions in a number of states have moved, or are moving, to require the undergrounding of electric distribution and communication systems. With the current public concern for environmental protection and aesthetics, it seems likely that more state agencies will require undergrounding if the utility companies do not voluntarily move in this direction rapidly enough.

As most utilities are located in street rights-of-way rather than on private easements where accessibility may be a problem, it follows that the undergrounding of these facilities will result in their placement under street pavement. This joint use of right-of-way gives rise to a number of conflicts which municipalities have attempted to control through the adoption of street opening regulations.

The number of street cuts in a typical urban community may surprise you. In a recent study by APWA, the cities of Denver, Los Angeles, and Montreal reported 45,511, 40,000, and 25,000 street cuts per year respectively. In Montreal, it cost $2 million to restore these pavement cuts. The cutting of pavement for installation and maintenance of underground utility facilities obviously impedes the flow of traffic, poses safety hazards both to the traveling public and the utility workman, pollutes the environment with construction dirt and noise, inhibits access to abutting properties, and does some damage to the structural strength and serviceability of the street no matter how well the pavement is restored. We don't know precisely what the total system costs of cutting pavements are (we are attempting to calculate this in a study that we are now doing for the Federal Highway Administration), but one estimate of the present worth of the costs of the traffic delays caused by 30 cuts per year on a 1-1/2 mile section of road is $281,000. This includes only the time lost by the motorist and the increased vehicle operating costs. When one adds the cost of pavement restoration, the cost of accidents of all kinds attributable to utility work in street rights-of-way and the less tangible cost to the abutting property owner of noise and dirt and so on it is apparent that these costs are considerable. They are borne in varying amounts by the operator of the utility, the local government, the highway user, the abutting property owner and the utility customer. The municipal official charged with regulating the cutting of street pavements is attempting at least to minimize the cost to the municipality and the motoring public. This is done typically by requiring the utility company to obtain a permit showing the location of the work, the amount of street to be opened and when the work is to be performed. The municipality may or may not require a performance bond. The municipality may require that work in certain busy areas of town not be performed during peak traffic hours, and that at least one lane of traffic be maintained at all times. The municipality will usually require that appropriate barricades and warning devices be installed to protect the public. A good guide to follow is the Manual on Uniform Traffic Control Devices for Streets and Highways published by the Federal Highway Administration which devotes about 53 pages to the subject of traffic controls for street and highway construction and maintenance operations. Many municipalities follow these practices although some have their own local modifications. The municipality is very much concerned with the backfilling of the trench, requiring either that the native backfill be compacted or if it is not suitable backfill material, that granular material be brought in. Backfilling requirements are often a bone of contention between the contractor and the municipal inspector. The municipality may also require that a temporary patch be placed over the trench and maintained by the utility company or its contractor for some period of time until traffic has compacted the fill. Some municipalities will allow or require the utility company or its contractor to restore the pavement according to municipal specifications; other municipalities prefer to do all pavement restoration with their own forces and bill the permittee for the cost of the restoration. Street opening regulations and permit fees vary from municipality to municipality and there are no nationwide standards for pavement restoration. However, a number of model ordinances have been aopted. The Southern California Chapter of the American Public Works Association and the Institute of Local Government of the University of Pittsburgh in cooperation with the Western Pennsylvania Chapter of the American Public Works Association both have developed good model street excavation ordinances. Many other municipalities also have good street opening regulations.

Municipalities take a very dim view of utilities cutting newly constructed or recently resurfaced pavements. Some municipalities have established programs whereby utility companies are given advance notice of the municipality's intention to pave or reconstruct various street segments. The utility is then given a specified period of time to install new underground facilities in that street or to do extensive repair work prior to the paving of the street after which the utility companies are either forbidden to cut the street except in an emergency, or are given stiff penalties for doing so within a specified number of years.

Some of the problems associated with the joint use of street rights-of-way for transportation and public utility facilities have already been mentioned. In addition to these problems, the accidental digup of underground utility lines is a problem that plagues many communities and utility companies. Such accidental digups are quite numerous. In a recent report prepared by APWA for a Symposium on Pipelines Safety, a gas company serving a four county area in the state of Washington reported over 1100 accidental digups in one year. One telephone company has reduced its statistics to a per mile basis -- approximately one accidental digup per year per 14 miles of buried cable. These accidents cause temporary service disruptions which may be the source of minor inconvenience or be of major moment due to the inability to communicate with the police or fire department or a doctor in the case of an emergency. The damage of gas pipelines has resulted in a number of explosions and numerous deaths in recent years. So the problem of the accidental digup of underground utilities is a real and serious one. A number of remedies have been proposed to alleviate this problem. They include the establishment of utility coordinating committees and the holding of pre-construction conferences, "call before you dig" programs, field location programs by utility agencies, improved permit procedures, better methods of information dissemination, improved recordkeeping, improved construction specifications, better field supervision, more hand excavation, standard utility location guidelines, the permanent marking of underground facilities, the judicious use of pipeline encasement, better definition of responsibilities between the contractors and the utility agencies, and the increased use of utility tunnels for accommodating utility plant in congested urban areas.

A number of communities have attempted to establish utility location standards or guidelines in the hope that a more regular and orderly arrangement of underground utilities might alleviate this problem. The San Diego Chapter of APWA, the City of Phoenix, and a number of other cities and groups of cities around the country have established utility location guidelines. The typical recommended location for telephone and cable television lines is under the sidewalk. In the current project that APWA is doing for the Federal Highway Administration we are going to try to identify the advantages and disadvantages and total system costs and benefits for various alternative locations and configurations of the mix of utility lines typically found in an urban street. The end product of this study is to be a manual of practice which will establish among other things standard utility location guidelines. This study is scheduled for completion by next summer. A large number of utility companies and professional associations interested in this work are represented on the steering committee of this project. The National Cable Television Association is represented by Mr. Charles Henry, the chairman of this session.

Apart from complying with relevant municipal codes and regulations there is one voluntary activity that I would urge all operators of cable TV systems to engage in. That is to join with other utility companies and municipal departments in the many utility coordinating committees that exist and are being formed throughout the country. It is the purpose of these committees to inform each member of the activities of the other agencies and to plan ways in which they might coordinate their efforts for their common good. The Los Angeles Substructure Committee and the Oregon Utility Coordinating Council are only two of the outstanding examples of what this kind of committee can accomplish on a voluntary basis. Many of these committees are responsible for "call before you dig" and "locate and stake" programs which protect their underground facilities and for the scheduling of their construction activities to realize the economies of joint trenching and in other ways minimize costs and delays.

Utility Tunnels

Another subject related to the underground location of utility lines is one that the American Public Works Association has been studying recently. That is the subject of utility tunnels. In 1970, APWA undertook a study sponsored by the Federal Highway Administration and a number of other agencies of the feasibility of utility tunnels in urban areas. This was followed last August by a conference co-sponsored with the Engineering Foundation on Engineering Utility Tunnels in Urban Areas. Both the proceedings of this conference and the report of this research project have been published and are available from the American Public Works Association. The conclusion of these investigations is that utility tunnels are technologically feasible. They have been used for years in Europe, Japan and to a limited extent on campuses and other large industrial and institutional sites in the United States. They can house the full range of power, communications, water, gas and other distribution systems and may well constitute the answer to the perennial problem plaguing many municipalities on how best to accommodate needed utility facilities in public street rights-of way without the mutual interference caused by the use in maintenance of these utility and highway systems. Placing utility lines in tunnels under public rights-of-way can avert the continual cutting of pavements and should facilitate the installation, inspection, replacement and maintenance of these facilities. A few technological problems must be resolved. The development of in-tunnel environmental standards and the engineering of safety and security systems must be accomplished, but these appear achievable. The institutional problems relative to working out the legal and cooperative arrangements for the construction, financing, management and joint use of these tunnels by a variety of separately owned utility agencies appears to be the major stumbling block. But it is expected that if the advantages of the concept can be domonstrated, ways will be found to overcome these obstacles, too.

Here are cross sections of some utility tunnels that are in existence. Notice the dimensions of the tunnel, the wide range of utilities included, and the placement of telephone cables on trays.

Slide 1 - Typical Section of a utility tunnel in London

Slide 2 - Utility Tunnel at Kiev, USSR

Slide 3 - Sidewalk Utility Tunnel in the Ginza District, Tokyo, Japan

Slide 4 - University of Washington Utility Tunnel

These tunnels are not dissimilar to the pipe galleries commonly found in water and wastewater treatment plants.

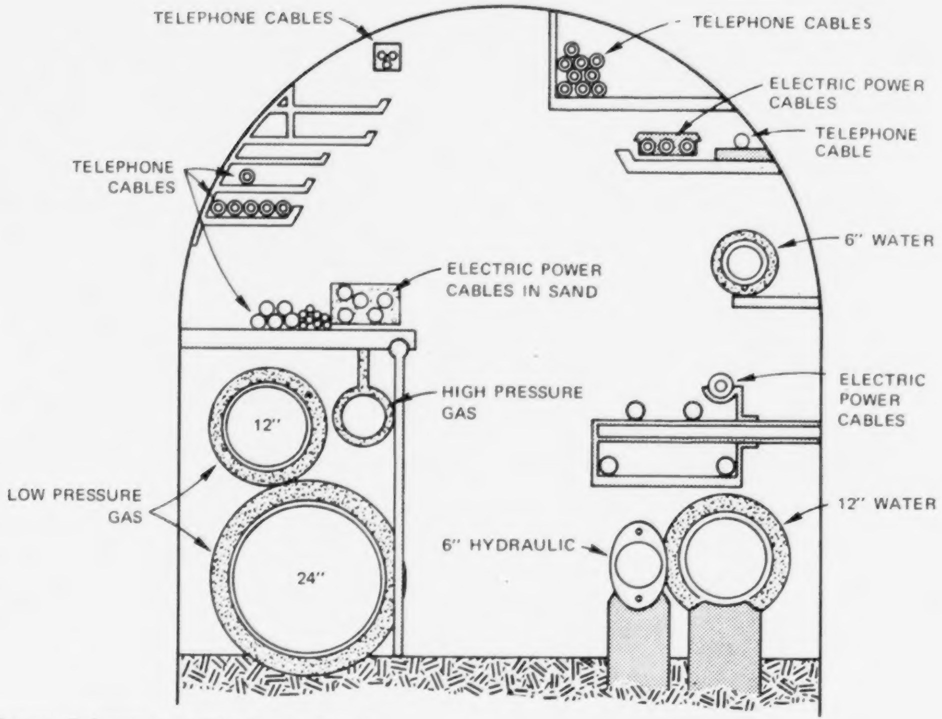
Slide 5 - A Pipe Gallery in A Wastewater Treatment Plant

We are convinced that the utility tunnel concept has real application, especially in dense urban areas, for the accomodation of underground utility systems. We urge you to consider the potential of this method for the installation of your underground facilities.

Conclusion

Time has permitted only a very cursory and generalized review of the municipal codes and regulations which affect the placement of cable television and other utilities in public street rights-of-way. In every case, it is necessary to consider the specific requirements of the particular agency with which you are dealing as practices vary from location to location throughout the country. I think you will find that most public works officials who administrer street regulation and utility coordination programs are honest and fair-minded individuals. They are doing the best they can to protect the considerable investment of the public in its highway system and to minimize the inconvenience and hazards to the public caused by the joint use of street rights-of-way for transportation and utility purposes. A cooperative attitude on the part of both the public official and the utility company will go a long way toward harmonizing the joint use of rights-of-way for the good of all concerned.

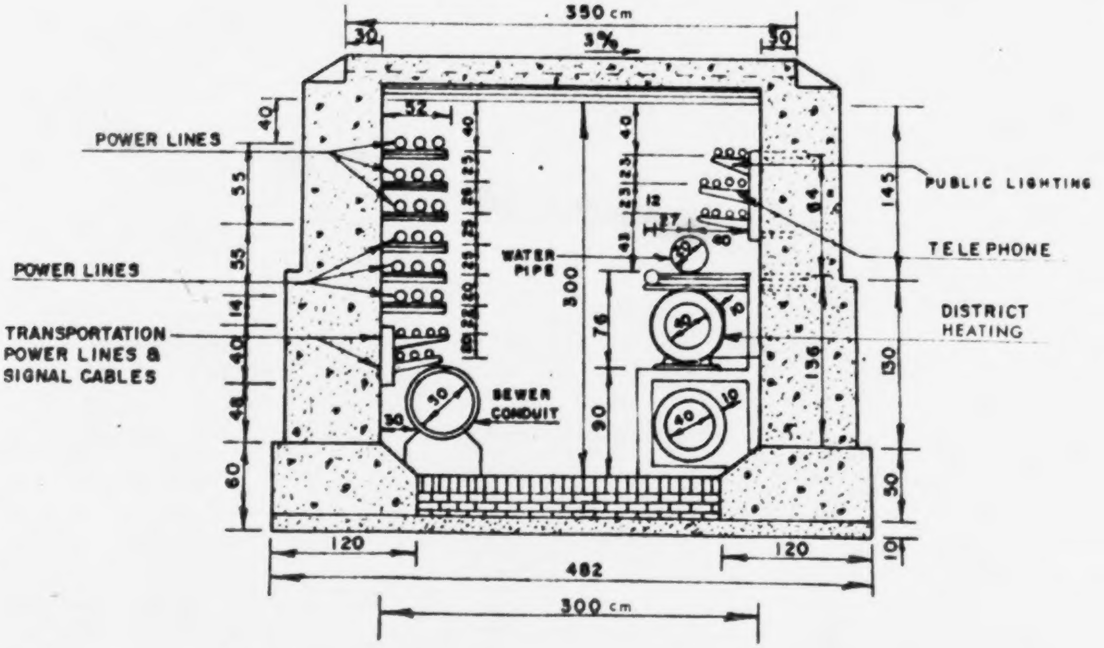
Slide 1.


TELEPHONE CABLES
TELEPHONE CABLES
ELECTRIC POWER CABLES
TELEPHONE CABLE
TELEPHONE CABLES
6" WATER
ELECTRIC POWER CABLES IN SAND
HIGH PRESSURE GAS
ELECTRIC POWER CABLES
12"
LOW PRESSURE GAS
12" WATER
6" HYDRAULIC
24"

Source: Reference 9, *APWA Report No. 39*

FIG. 4–Typical section of a utility tunnel in London.

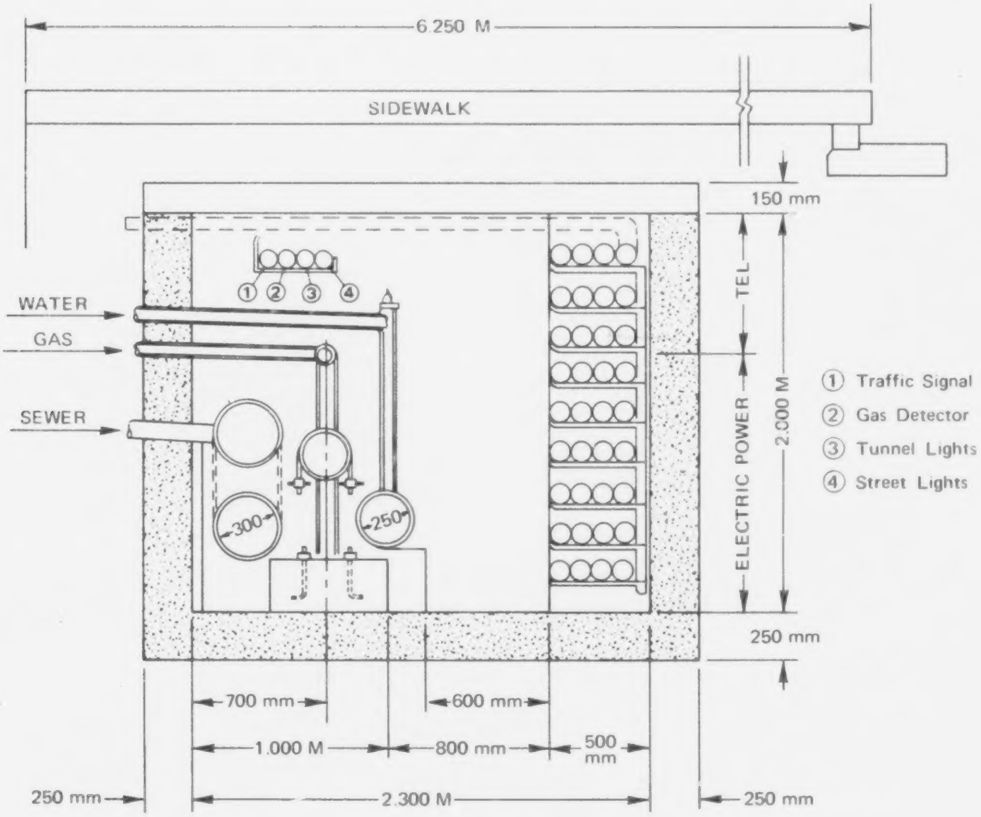
Slide 2.


350 cm
30
3%
30
40
52
POWER LINES
55
55
POWER LINES
14
TRANSPORTATION POWER LINES & SIGNAL CABLES
40
45
60
40
23
23
25
25
23
25
23
50
25
150
WATER PIPE
300
40
23
23
12
27
43
80
PUBLIC LIGHTING
TELEPHONE
84
145
DISTRICT HEATING
76
15
136
130
30
SEWER CONDUIT
30
90
40
10
30
120
120
10
482
300 cm

Source: Reference 4, *APWA Report No. 39*

FIG. 5–Utility tunnel at Kiev, USSR.

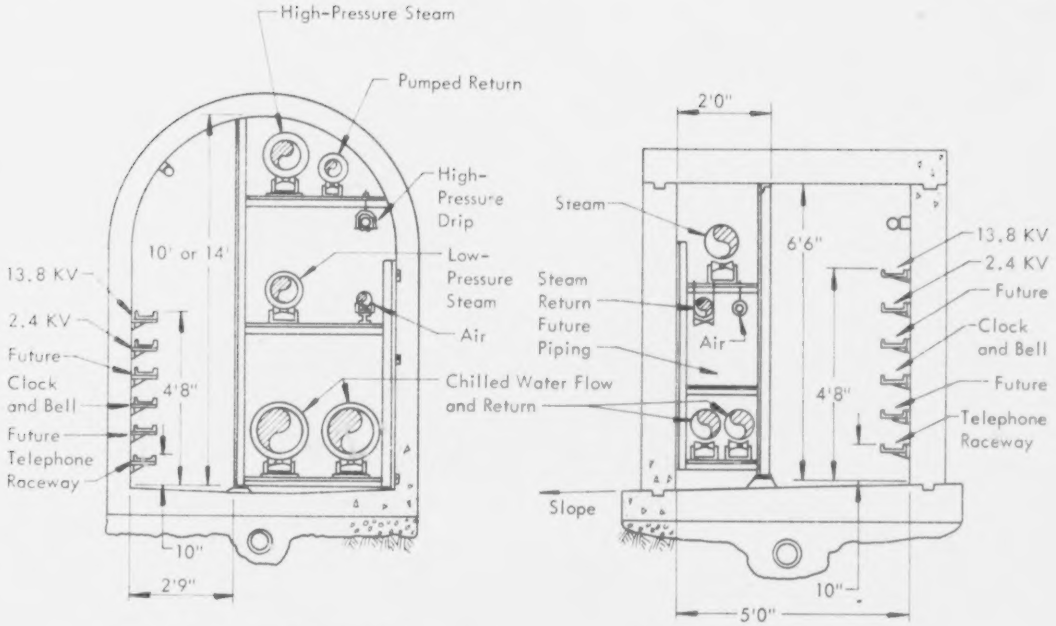
Slide 3.


6.250 M
SIDEWALK
150 mm
TEL
ELECTRIC POWER
2.000 M
250 mm
WATER
GAS
SEWER
① ② ③ ④
300
250
① Traffic Signal
② Gas Detector
③ Tunnel Lights
④ Street Lights
700 mm
600 mm
1.000 M
800 mm
500 mm
250 mm
2.300 M
250 mm

Source: Reference 22

FIGURE 26 – SIDEWALK UTILITY TUNNEL IN THE GINZA DISTRICT, TOKYO, JAPAN

Slide 4.


High-Pressure Steam
Pumped Return
High-Pressure Drip
Low-Pressure Steam
Air
Chilled Water Flow and Return
10' or 14'
13.8 KV
2.4 KV
Future
Clock and Bell
Future
Telephone Raceway
4'8"
10"
2'9"
2'0"
Steam
Steam Return
Future Piping
Air
6'6"
4'8"
13.8 KV
2.4 KV
Future
Clock and Bell
Future
Telephone Raceway
Slope
10"
5'0"

Left – Tunneling Construction **Right – Open Cut Construction**

Source: Oak Ridge National Laboratory

FIGURE 1 – UNIVERSITY OF WASHINGTON UTILITY TUNNEL SECTIONS

Slide 5.

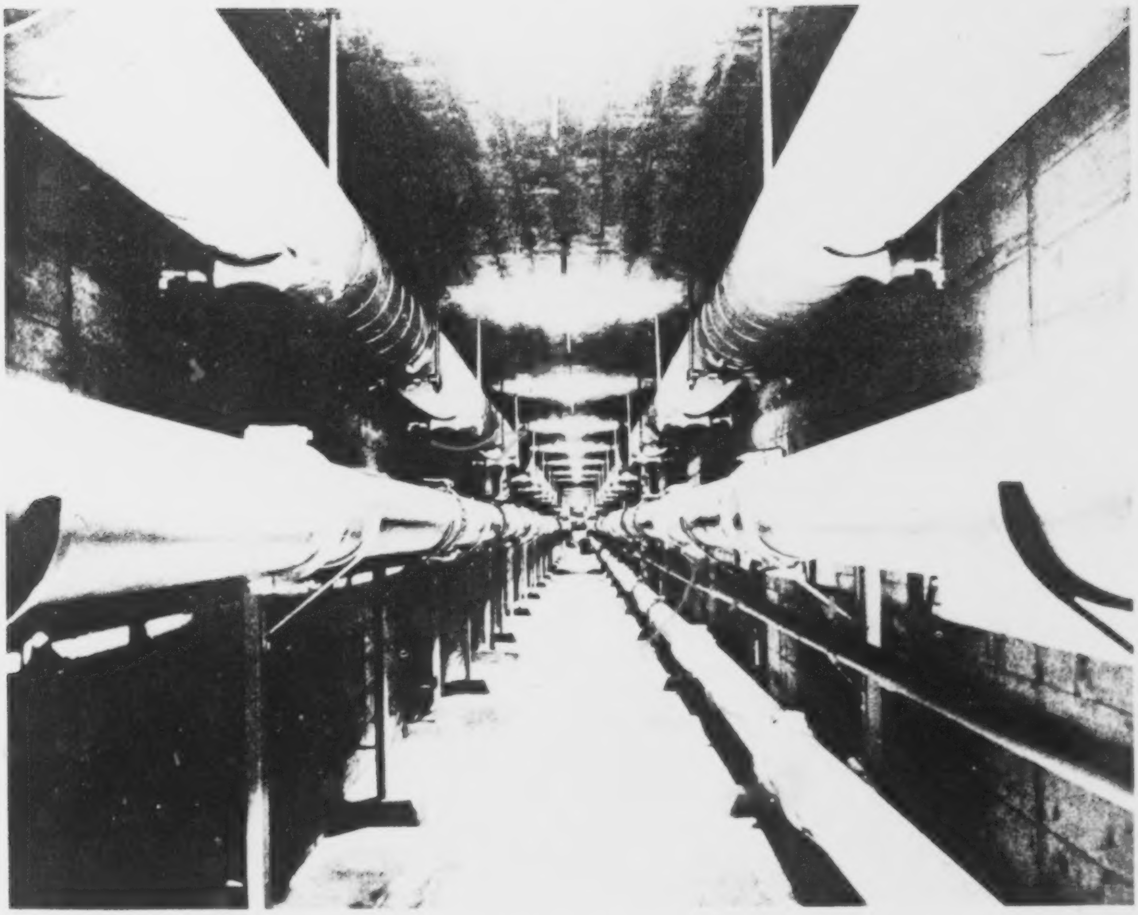


FIGURE 4 – A PIPE GALLERY IN A WASTEWATER TREATMENT PLANT INCLUDING STEAM, SLUDGE, FRESH AND RECLAIMED WATER LINES

HIGHLIGHTS - UNDERGROUND CONSTRUCTION TECHNIQUES

Theodore J. Swanson & J. Robert Bird
Cypress Communications Corporation
Los Angeles, California

Good Afternoon Gentlemen:

I feel I am conversing to an audience having a considerable level of expertise in underground construction. Therefore, it is my intention to limit my comments to lay terms instead of a highly technical presentation. I hope our comments today will contribute to your understanding and enlightment concerning the technology of underground cable television facilities. My colleague, Mr. Bird, will later cover some of the techniques in further detail. I feel we will only touch on generalities in our discussion as there are many facets of concern in the topic matter before us.

With the continuing pole rental increases, difficulty in obtaining pole contracts and, in some cases, the requirements of franchises and pole contracts, underground cable installation is becoming more common throughout our industry. Beautification groups demand it, public utilities are headed more and more in this direction and cable operators are receiving constant pressure to adopt this method of plant installation.

Although underground installation has been practiced for years by the utility companies, it is a relatively new concept for the CATV industry. And, as with anything we lack experience in, hesitancy, apprehensiveness and phobias exist.

COST CONSIDERATIONS

Gentlemen, if you don't have to go underground with your cable facilities, just simply don't do it! However, if for physical and legal reasons you are forced to consider installing your cable facility underground, then by all means check your bank accounts - because I can assure you it is an extremely expensive venture and the costs involved are not consistent with the revenues generated by today's cable system rates and accepted amortization schedules.

I recognize that in the future, we are definitely going to hav to anticipate and construct many miles of underground CATV facilities. However, I find that many of our constitutents generally approach underground construction with attitudes and cost projections based on overhead construction experiences from their past. This is the first major error that many of us make when anticipating underground construction. I personally have found it extremely difficult to develop and forecast accurate financial projections and underground construction schedules. This is particularly true where construction is anticipated in major metropolitan areas such as New York, Chicago or other top 100 Market Areas. One of my colleagues today on the panel has/or will touch briefly on cost factors involved with placing underground facilities. However, I feel it prudent to mention some of the more difficult cost factors involved with underground construction. The following areas of concern should be approached with diligence, and experience in order to develop accurate cost projections. They are:

1. Cost of developing right-of-way and easement.

2. Cost of concrete or pavement cutting, boring and trenching. This is particularly true in areas that are highly developed and covered with sidewalk and/or paved streets and alleys; i.e., we find that in California many of our backyards where utility easements are available are also enclosed in brick or wooden fences thereby causing a considerable amount of variables in finalizing cost factors.

3. Cost factors involving the labor and material for the project itself.

4. Cost factors involved with maintaining on-site supervision when the facilities are being placed in joint trench facilities. This is particularly true where other contractors are working in common facility over a longer period of time. Unless the cable company supervises and maintains someone on the site, the chances of damage to conduit or cable are extremely high. We find it to be an almost necessity to maintain someone at the construction site until all activities have ceased and the conduit or cable is buried.

5. Cost of cover-up, impacting the fill, blackcapping and/or landscaping.

ENGINEERING CONSIDERATIONS

Most of today's operators have generally experienced engineering which involved overhead plant facilities and some of you have encountered underground construction in areas where engineering considerations are similar to those of the overhead plant. However, I wish to point out that in many of today's metropolitan and urban areas the engineering prints and concepts for an overhead plant cannot generally be used in order to obtain the necessary permits and authorizations to place your facility in private or municipal-owned rights of way beneath the surface.

Experience has shown that a certain amount of civil engineering practice is necessary in order to properly design and sketch the underground facility. This is generally true where the municipal authorities are concerned for other utilities that may exist beneath the surface, such as water, gas, power and telephone, particularly if the cable entrepreneur is the latecomer. In this case, accurate and well-designed engineering sketches must be prepared in order to obtain the necessary authorizations to uncover the streets, bore under sidewalks, etc. While the engineering of the electronic facilities remain similar to the overhead plant, we find the underground physical design to cause almost as much concern and it should be accomplished by engineers having a mechanical or civil engineering background.

If any of you in the audience are planning on constructing facilities in some of the more developed downtown areas, I would suggest that you attempt to hire individuals who have had experience at designing and placing underground utilities when augmenting your staff. People with this type of background and experience are available in most communities. We have found a considerable amount of assistance from former retired telephone plant engineers or municipal civil engineers who would welcome the additional income.

CONDUIT -- WHY

We at the Cypress advocate and construct most of our underground cable underground plants with conduit. We recommend and advocate its use generally because we feel it provides the convenience of future maintenance and refurbishing. Additionally, we feel that there may be the potential possibility of additional future revenue generation by having the conduit placed to enable routing to all homes in new developments and tracts.

As an example, in the latter 1800's the city of New York franchised various entrepreneurs to place conduit within the streets of New York. Today, these conduits and right-a-ways are highly overburdened with communication facilities. However, if it were not for the early development of these communications paths the installation of cable and telephone facilities would be almost an impossibility. In California for a cable operator to consider construction of a cable system after a tract or housing development is fully developed with paved streets, concrete block walls, etc, we must anticipate a tremendous increase in the cost factors that I mentioned earlier. Therefore, we feel it advisable to attempt to get conduit facilities installed at the time the joint trench facility is opened, even though some costs and carried interests are generated until the cable plant is installed and activated. Having the conduit installed at an earlier date will allow the installation of cable and electronic facilities when the tract is fully developed and when CABLE TV would be a financially successful endeavor. Additionally, the early installation of these conduit routes also allow installation without future complications of street borings and the enclosure of private property with fencing and landscaping.

CONDUIT VS. DIRECT BURIAL

Usually one of the more direct questions that one encounters in the decision-making process is whether or not the cable installation should be made with conduit and coaxial cable or whether the coaxial cable should be armored and placed directly without the use of the conduit environment. This particular question has caused a considerable amount of rhetoric in the past and I am sure will be even more controversial as the technology developes in the future.

Most of our telephone company colleagues today will recommend the placement of armored buried cable in their plants. They point out that with proper design, their systems can be planned for future growth, and technology changes. Most of the utility companies have had more than 30 years of historical documentation to prove that the properly designed cable facility can be buried directly without the concerns that I express. It has been my general experience, however, that the Cable TV and cable technology has been in a constant state of change. As an example: Most cable plants placed five years ago, today will not handle 20-channel two-way transmission that the present industry is recommending. In many cases, we already are considering the refurbishing of systems constructed within the last five years.

I feel that todays' embryonic cable technology has not yet developed in comparison with the telephone-type cable. Additionally, our comrades in the utilities companies are not making use of extremely broadband, coaxial RF transmission techniques, therefore, it is difficult to compare the two technologies in order to arrive at a conclusion. I feel that the advantage of having the capability to remove and refurbish today's cable facilities will far outweigh the cost factors of having to completely retrench and reconstruct the plant for future "state-of-the-art" changes.

There are areas where direct burial of CATV facilities should be considered, they are:

1. Rural areas where long cable runs are involved.
2. Existing tracts or developments where economics of cable operations prohibit the placement of conduit type facilities.
3. Underdeveloped areas where extensive streets and sidewalks have not been developed.

POLYETHYLENE VS. POLYVINYL CLORIDE CONDUIT

Once the posture and necessity for an underground plant is decided, we generally face the various questions of materials to be used in its construction. One of the first considerations will be the type of conduit that should be used if conduit is anticipated.

In general, there are two types of conduit configurations that are widely accepted by the industry, they are: Polyethlene and Polyvinyl Cloride which is sometimes referred to as PVC.

Polyethylene usually comes in 300 ft. rolls or shorter; it is a soft and semiflexible material.

Its advantages are:

1. Extremely easy to place in trench with a minimum amount of labor.
2. Can be bent to make corners and curves without special elbows and plumbing. However, it requires special coupling and sealing methods.
3. It is generally cheaper and quicker to install.

Its disadvantages are:

1. It is hard to handle and store. It is bulky and difficult to ship from manufacturer to consumer.

2. It cannot be glued or sealed like the PVC due to its inherent properties. One must consider the use of heat shrinkable tubing or splicing sleeves which are especially made for installation.

3. It can be easily collapsed by rocks and pressure if care is not undertaken in its installation. One must be careful to not purchase extremely thin-walled conduit when polyethylene is used.

4. It is difficult to use when sharp bends and short radii are encountered in the trench or right-of-way. Various configurations of flexible conduit and adapters must be considered in order to make a watertight environment.

PVC

PVC is a space-age material presently being used for water-pipe, containers, and other industrial products. Its advantages are:

1. It comes in straight 10, 20, and 30-ft. sections which are easily shipped and stored.

2. It can be easily adhered-to or glued by special solvents allowing an effective seal from hostile environments.

3. It is manufactured with preformed splices, bends and sweep radii which are necessity in order to pull the coaxial cable.

4. It is easy to plumb and makes a very neat installation.

5. It presents a smooth even surface in order to facilitate pulling the coaxial cable.

Its disadvantages are:

1. Generally costs 20 to 30% more than polyethylene.

2. Requires more labor to install.

3. Requires consistent chemical properties and wall thickness or it can be easily shattered by rocks or sharp blows of the worker's tools.

Generally, in our operations, we prefer to use PVC type conduit. However, in sandy areas and where economics play an extremely important factor in its construction, usage of polyethylene conduit is widely accepted as a substitute.

Whether PVC or polyethylene conduit is used for underground facilities one should be extremely careful to assure that it is continuously sealed from rocks, mud, water and foreign material. These cautions must be observed both during the installation of the conduit and after the installation of the cable.

CONDUIT TRACING AFTER INSTALLATION

As I mentioned earlier it is sometimes advisable to install conduit prior to the installation of the cable and electronic facilities. This is usually the case when a tract is being developed and sold over a long period of time and the utilities generally are placed at a date prior to the construction of homes and dwelling units.

It is general policy within our company to install conduit in these tracts at a time when the joint trench is opened. However we have encountered various problems when the cable and electronic installation is made at a later date.

Some of these problems have been:

1. Muds, water and rocks in conduit preventing the pulling of cable.

   . To prevent entrance of foreign objects and water entering the conduit, it is necessary to seal the conduit properly during its installation and thereafter.

2. Broken conduit.

3. Lost conduit.

   a. Many times after these problems have been solved, we find it impossible to trace the conduit routes under the surface.

   In all installations you should attempt to keep conduit units to 300 ft. using access boxes, to enable pulling cable without excess tension, and to also enable later removal and replacement.

> This is particularly true when streets and landscaping have been completed and the actual conduit route has been lost.

Whenever conduit is placed, it is advisable to assure that a pull wire or rope is installed. This will enable later pulling of the coax. We have found it helpful to place a stainless steel wire (.045 lashing wire will suffice) in the conduit at the time of installation. This wire can be used later to pull a heavier pull line through the conduit. However, its most important aspect is that one can attach a signal generator to the wire and with the use of a pipe tracer or metal detector one can trace the conduit routing under the surface of the ground. This can be most helpful in finding conduit breaks and routing. Therefore, I would recommend inserting a metallic conductor whenever a conduit is placed without immediate coaxial installation.

I would like, at this time, to turn the presentation over to my colleague, Mr. Bird, who will continue with the discussion.

Good Afternoon Gentlemen:

Underground installation can open Pandora's Box, or at least give us a good look inside. And unfortunately, we do not have a history established on the few systems with underground plant. Consequently, there are numerous areas of unanswered questions such as, maintenance, electronic design, type of cable, direct burial cable versus conduit and installation, to name a few. Each of those areas and many more would be a subject to itself. However, it is the installation technique I would like to address in this presentation.

TRENCHING VS. PLOWING

There are two methods of installing buried cable, plowing and trenching. It has been suggested that the plowing method be used when the soil is sandy and relatively rock free, but there are definite disadvantages in using the plowing method regardless of the type of soil. Plowing does create a mess.. The trench is dug too quickly with total disregard for whatever other facilities are underground. It is true the workmen doing the actual digging should contact all the people who may have underground facilities in the area. But, it is generally impossible to locate every drop, power feed, water pipe, etc. which has been buried. Consequently, something is constantly being cut, work stopped to enlarge the hole for repairs, a mad customer or potential customer, strained relations with a utility company, time lost and in the case of a water pipe, a large muddy hole, not to mention the cost of repairs.

Therefore, the plowing method should be restricted to areas which are rural or to new housing developments where underground installation is being originated and nothing has been placed underground up to that point.

Trenching, on the other hand, is much slower, but because it is slower, the problems I have previously mentioned are less likely to occur. The trencher operator is standing behind the machine and is able to observe where and what he is digging.

Also, the trenching method allows the operator access to confined areas which would be impossible to dig with a plow such as close to walls, fences, etc. Trenching, of course, is the only method which can be used when asphalt or cement removal and replacement is required. This is due to the confined working space and the necessity of leaving a 2" to 4" shoulder for paving replacement.

After the trench is opened, a 1" to 2" sand bed must be placed at the bottom of the trench as a cushion for the cable. The trench should be inspected for any sharp rocks or other objects which may be protruding from the sides. Those, of course, should be removed in preparation for the cable.

CABLE INSTALLATION

As to the installation of trunk and distribution cables, the practice of unreeling the cable parallel to the trench and then lowering the cable is a poor practice. While the cable is on the reel it is afforded the maximum amount of protection. To unreel the cable and place it alongside the trench is to expose it to abuse from the men and/or equipment working in the area. I am referring, of course, to direct buried cable. When using conduit this problem does not exist as the cable is fed directly into the conduit. When placing direct buried cable into the trench, the reel should be placed at the head of the trench in such a manner so the cable unwinds from the bottom. The pulling mechanism, should it be a pulling reel, take-up wench or whatever, should be located as near the other end of the trench as possible. The pulling cable is then attached and the cable pulled directly into the trench at a pulling speed not to exceed 60 feet per minute. A workman is positioned at the cable reel to assist the cable from the reel and to perform a visual inspection of the cable as it enters the trench.

After the cable has been placed into position it should be covered with another 1" to 2" layer of sand and then the trench backfilled and tamped completely.

When using conduit the same trench preparation and installation methods should be used. In the event of conduit usage, I recommend that an empty conduit placed in the trench of adequate size to accommodate two extra cables. This may sound economically extravagent, however, even today we are uncertain as to the extent of services we can or will be required to provide in the future. This extra conduit will provide for future system expansion.

This extra conduit should be brought well into each pedestal and capped to preserve its integrity. When using conduit in underground systems further precautions must be observed.

A lubricant must be applied liberally to assist the cable through the conduit. Also, cable pulling tensions according to manufacturers specifications must be adhered to, and pulls in excess of 300 feet should be avoided due to possible cable damage. It is also recommended that small holes be bored in the conduit at low points to provide a drain for moisture which may accumulate.

PEDESTALS

I won't argue the merits of flush mounted versus upright or exposed pedestals as this is usually dictated by the franchise requirements. But regardless of which method is permitted, one of the most important considerations is weather-proofing. Moisture is a constant source of trouble in an underground system and special precautions must be taken to protect against it. In a total underground system the use of cement water boxes as a protective housing is common in conjunction with a plastic capsule to house the equipment. This practice and the use of heat shrinks on the leads has proved to be satisfactory in most cases. However, this presents the problem of condensation. Since we are airtight, the plastic has the tendency to "sweat" with no escape for this moisture. This can be eliminated through the use of a small cheese-cloth sack of calcium chloride placed inside the capsule to absorb the condensation. This also holds true when using upright plastic pedestals.

Considerations for upright pedestals should include immunity to weather and soil conditions, minimum maintenance such as painting, attractiveness and protection against vandalism. In both methods, adequate lengths of cable should be left in the housings to accommodate future maintenance requirements such as connector replacement or repositioning of equipment.

SPLICING

When initially installing the trunk and distribution cable the need for a splice should never occur. The necessity of a splice at this time is inexcusable. Customizing cable lengths to accommodate distances between amplifiers is necessary and must be done throughout the plant. After each reel is swept in the shop, it should be designed for a specific location and a record kept of its characteristics and where it was placed.

However, after initial installation it is inevitable that the cable will be cut and a splice required. When this occurs, a pedestal or water box should be installed at this location and the splice placed inside this housing. Should the splice occur in a feeder, a directional tap should be installed which can then serve as a test point in case of later trouble in this line. This may seem economically unfeasible, however, the best splice made by a technician will, at some time, be a source of trouble and the quicker and easier it can be checked, the faster you can clear tne problem. On the other hand, if you have to locate a splice underground, dig for it and then repair it, the cost of labor has more than exceeded the investment of a pedestal or directional tap.

RECORDS AND MAPS

I would like to touch on one other aspect of underground plant which, is too often overlooked - and that is accurate maps and record keeping. By going underground the advantage of physically observing the plant is lost - making accurate maps and records even more mandatory and valuable than before.

The construction supervisor should have a complete set of maps with him on the job site at all times as should each of his foremen. As construction progresses these maps should denote the cable, the distances between amplifiers and other equipment and their exact locations in respect to permanent landmarks. After construction is completed these maps are compiled into an "as-built" map and copies given to all maintenance employees. As changes occur in the system these maps should be immediately up-dated. Records should include accurate flow charts on each amplifier, equalization methods, cable characteristics and a maintenance record on all amplifiers. I cannot stress strongly enough the importance of accurate maps and records in an underground system. This may force the system operator to create a new position on his staff to maintain this information, but it will certainly be one of his better investments.

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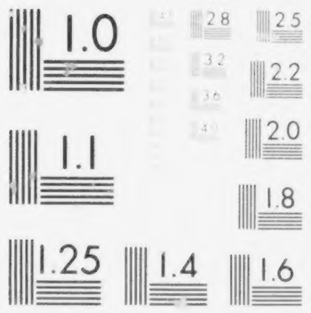
1.0
2.8
2.5
3.2
2.2
3.6
4.0
2.0
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1.25
1.4
1.6

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963-A

SIMULATED ENVIRONMENTAL AGING OF CATV CABLE

Richard V. Barone
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Abstract

Residual compressive stresses in CATV cable were measured using the parameter of aluminum shield removal force. Values for 0.412, 0.500, and 0.750 inch diameter CATV cables were measured for contact lengths of 2-1/2, 5 and 10 inches in the as-received condition. A series of time-temperature exposures ranging from ambient to 160°F and 15 to 1920 minutes were run on 0.500 inch diameter cable after which aluminum shield removal force measurements were made on specimens having a contact length of 2-1/2 inches. The rapid rate of decay at times and temperatures easily encountered in the field suggest that high compressive forces imposed during manufacturing for the purpose of minimizing moisture absorption, may exist for only a short time since environmental conditions may anneal out the residual stresses. Another fact of interest was that the center conductor/dielectric bond is chemical in nature and stronger than the plastic itself, whereas, the aluminum shield/dielectric bond is strictly mechanical in nature.

Introduction

The Community Antenna Television Industry has been characterized by continual technological advancement over a relatively short span of time. Characteristic examples include increased transmission distances, expansion of the carrier wave to the high UHF channels, reduced non-uniform attenuation of the signal, and reduced attenuation of the signal over the entire spectrum. Many of the improvements were directly attributable to improvements in the cable materials or the manufacturing method involved in making the cable. Arbuthnott[1] points out that prior to aluminum sheathing, jacketed foamed polyethylene cables were capable of picking up sufficient moisture through the jacket and into the foam insulation to cause excessive increases in signal attenuation. Increases could exceed 20% at Channel 13 in periods of less than six months. Aluminum sheathed cable eliminated transverse moisture penetration provided that the cable had no breaks. Connector improvements were also made to minimize any longitudinal moisture penetration at the dielectric/sheath interface. Manufacturing steps such as compressing the aluminum sheath tightly around the dielectric is also common practice and is claimed to minimize longitudinal moisture penetration and associated signal attenuation.

Background

Our interests focused on seamless aluminum shielded CATV cable with a foamed polyethylene dialectric as this constituted a major part of the market at the time of our investigation. This type is schematically illustrated in Figure 1. This material is manufactured by coextruding the center conductor made of either copper clad aluminum or copper and the foamed polyethylene. This combination is then inserted into an aluminum tube and the aluminum tube drawn down around the polyethylene and center conductor so that the dielectric is compressed and a tight, moisture prohibiting joint exists.

As a series of preliminary measurements to characterize fundamental cable properties, tests were performed to determine the bond strength of both the center conductor/dielectric and the dielectric/aluminum shield bonds. This was done using an Instron Testing Machine and the fixtures shown in Figure 2a and b. The fixture consisted of a die which would restrain the shield and dielectric while the center conductor was being pulled to determine the center conductor/dielectric bonding force and another die with a larger opening which would restrain only the aluminum shield so that the dielectric/shield bond could be determined.

Procedure

The initial series of measurements were made on a number of cables in the as-received condition made by different manufacturers to represent a characteristic cross section of the industry. Cables having an outside diameter of 0.412, 0.500 and 0.750 inches were tested. In addition, the contact length which was sheared was varied, i.e., specimens with 2-1/2, 5, and 10 inches of contact between the center conductor/dielectric and dielectric/aluminum shield were tested. This is schematically shown in Figure 3. Specimens from a manufacturer for each diameter with both copper clad aluminum and solid copper center conductor were tested if possible. The detailed specimen preparation is listed in Appendix I.

Results

The results of the initial series of tests are shown diagramatically in Figure 4 for the shield removal forces and Figure 5 for the center conductor removal forces. Individual test values, the maximum ones attained, are listed in Tables 1 and 2 respectively.

The nonlinearity of force for either the aluminum shield removal measurements or the center conductor removal force with respect to contact length indicate a mode of failure which is partially wavelike in character. However, both the shield and center conductor removal forces increase with increasing contact length as shown in Figures 4 and 5 so that there is a length factor involved. The increase in force with contact length is characteristic of a single event. Thus, there is a duality to the failure mode of both the shield removal and center conductor removal from the cable. Figure 6 is an illustration of the types of typical stress strain diagrams that resulted in either the shield removal or center conductor removal measurements.

Type I represents a characteristic plastic/metal bond separation. Note that the force measurement does peak followed by a relatively sharp drop in the stress. The initial portion of the curve was either smooth or contained minor perturbation steps which appear to be caused by small areas of the bond being broken. The stress then increases until the entire interface shears and the stress falls to a level necessary to overcome the friction drag of either the center conductor and the dielectric or the dielectric and the aluminum shield as they are being removed.

Type II behavior is typical of when a center conductor yields and fractures. This is essentially a tensile strength curve for the metal center conductor.

Bond Characteristics

The initial test observations of the center conductor removal and shield removal specimens illustrated that the nature of the bond between the center conductor and the dielectric and the dielectrical aluminum shield were significantly different. The shield was clean with virtually no dielectric adhering to it after the polyethylene and center conductor were removed from it.

This shows the bond to be mechanical and that friction is the prime retardant to hold the dielectric in contact with the shield. In contrast to this when the center conductor was pulled from the dielectric it had polyethylene adhering to it which shows the bond to be more than mechanical. This difference is attributable to the manufacturing in which the foam polyethylene is coextruded hot around the center conductor. This gives rise to the strong bond between the polyethylene and metal center conductor which must have been even stronger than the dielectric itself since fracture occurred within the polyethylene rather than at the polyethylene/metal interface. The aluminum shield/polyethylene, on the other hand, appears strictly mechanical. It is formed cold by drawing the tubing around the polyethylene center conductor core so there is no chance for the dielectric to melt and adhere to the aluminum shield.

Atmospheric Exposure Tests

Cables which were left outside over the summer months (approximately seven months) were sampled and tested before and after exposure to see if any changes in the shield removal force had occurred. Typical values observed for Brand 1 for 0.412, 0.500, and 0.750 inches diameter cable using a 2.5 inch contact length are listed in Table 3. The trend to drop in value indicated that some form of relaxation had occurred in the cables. This led to the series of experiments to determine if the relaxation was due to thermal means. Preliminary tests on several cables heated to temperatures between 140°F and 160°F showed that the center conductor removal force was affected very little while the shield removal force dropped considerably. These results led to a series of experiments involving measurement of the shield removal force as a function of time and temperature in an attempt to quantify the relaxation of properties by artificially aging them through thermal exposure. For these tests, the Brand 1, 0.500 inch diameter with a 2.5 inch contact length was chosen as representative. Specimens were made and tested according to Appendix I after thermal aging at temperatures of 120°F, 140°F, and 160°F. These temperatures were chosen to cover the range of those which could be experienced in the field on a hot sunny day by a black jacketed cable. Thermal measurements of temperatures obtained at the Attleboro test site of a black jacketed cable reached 140°F on a day that was in the low nineties so that higher temperatures could be expected in many areas since Attleboro weather is temperate in nature.

The results of the aging tests are listed in Table 4 and plotted in Figures 7 and 8. The results follow traditional trends of a thermally activated process, that is a more rapid reduction of properties with increasing temperature. Shield removal forces also appeared to asymtotically approach a limiting value for each temperature so that after 240 minutes at temperature only minor reductions would be expected if longer exposures were encountered. It is interesting to note that if the initial properties of a CATV cable are known then a fair approximation of the temperature experienced by the cable could be estimated by measuring the shield removal force after environmental exposure.

One exception of reduced properties with increasing time at a given temperature was observed for the 1920 minute series for the 0.750 inch diameter cable. This may have been due to a slight temperature variations as the 1920 minute specimens were run at a different time from the other specimens.

The degree to which the shield removal force fell off after a relatively short exposure to temperatures which can be encountered in the field during the warmer months raises the question of the utility of using high reductions on the aluminum to induce high compressive forces on the dielectric. Inducing large compressive forces within the cable would intuitively require a larger expenditure of energy and thus be more expensive. Arbuthnott's gas leakage test work shows that high compressive forces are not necessary for moisture penetration inhibition. His test involved subjecting 5 foot long samples to a pressure of 5 psi at one end of the cable and collecting the gas which escaped at the other end of the cable. He reports that cables which experienced moisture penetration into cables (causing as much as 15% attenuation in three months of exposure) leaked at rates several orders of magnitude higher than properly made cable. This particular failure was caused in manufacturing by improper extrusion techniques. His work shows that lower shield compression forces (on the order of those measured on Brand 3) are adequate to provide low gas leakage rates if extruded properly during manufacturing.

Based on the simulated aging experiments it also appears that if large compressive forces are induced they will not be maintained if temperatures in the range of 140°F to 160°F are encountered. As previously mentioned, these temperatures are easily encountered in temperate climates including that of New

580

England if black jacketed. It also indicates that if the cable is installed near heat sources, e.g., chimneys, stacks, etc., similar relaxation would be anticipated.

Conclusions

1. The significance of the high stresses induced in the dielectric by some manufacturers in order to minimize longitudinal moisture absorption is questionable based on the literature available. The retention of the residual compression for long periods of time is doubtful since thermal relaxation induced by normal environmental exposure is capable of reducing the stress level in a relatively short time.
2. The center conductor/dielectric bond is chemical in nature and even stronger than the dielectric itself, whereas, the aluminum shield/dielectric bond is strictly mechanical in nature.

Acknowledgments

I would like to thank Frank Spexarth and John Fan for their comments and suggestions; Norman Hindley and Rene Langlais the principle technicians handling the experimental tests and Bob Laverdiere for the artwork.

Bibliography

1. Arbuthnott, Jack Jr., 18th Annual NCTA Convention Official Transcript, Rx: Cable Prescription for the Future National Cable Television Association June 22-25 1969 San Francisco Hilton p396-404.

TABLE 1

ALUMINUM SHIELD REMOVAL FORCE (POUNDS)

Manufacturer	Diameter	Center Conductor	Specimen Length 2-1/2"	5"	10"
Brand 1	0.750	Cu/Al	150 (60)**	170 (34)	350 (35)
Brand 2	0.750	Cu/Al	120 (48)	260 (52)	372 (37)
Brand 3	0.750	Cu	17 (6.8)	9 (1.8)	15 (1.5)
Brand 2	0.750	Cu	134 (54)	260 (52)	390 (39)
Brand 1	0.500	Cu/Al	90 (36)	115 (23)	125*
Brand 3	0.500	Cu/Al	1 (.4)	2 (.4)	4 (.4)
Brand 1	0.500	Cu	80 (32)	148 (30)	200 (20)
Brand 2	0.500	Cu	82 (33)	160 (32)	250 (25)
Brand 1	0.412	Cu/Al	110 (44)	112*	112*
Brand 3	0.412	Cu/Al	15 (6)	22 (4.4)	30 (3.0)
Brand 1	0.412	Cu	138 (55)	175*	180*
Brand 2	0.412	Cu	96 (38)	176 (35)	182*

* Center conductor fractured prior to shield removal.

** Units of parenthesized figures are pounds/inch of contact length.

TABLE 2

CENTER CONDUCTOR EXTRACTION FORCE (POUNDS)

Manufacturer	Diameter	Center Conductor	Specimen Length		
			2-1/2"	5"	10"
Brand 1	0.750	Cu/Al	260 (104)**	315 (63)	320*
Brand 2	0.750	Cu/Al	310 (124)	375*	375*
Brand 3	0.750	Cu	260 (102)	280 (56)	400 (40)
Brand 2	0.750	Cu	320 (128)	440 (88)	500 (50)
Brand 1	0.500	Cu/Al	125*	125*	125 (12.5)
Brand 3	0.500	Cu/Al	120 (48)	128 (51)	138*
Brand 1	0.500	Cu	128 (51)	185 (74)	225 (22.5)
Brand 2	0.500	Cu	155 (62)	215 (86)	250 (25)
Brand 1	0.412	Cu/Al	130*	110*	112*
Brand 3	0.412	Cu/Al	81*	92 (18)	125 (12.5)
Brand 1	0.412	Cu	170*	180*	180*
Brand 2	0.412	Cu	150 (60)	235 (47)	307*

* Center conductor fractured prior to pulling out of the polyethylene.

** Units of parenthesized figures are pounds/inch of contact length.

TABLE 3

Aluminum shield removal force for 0.750 inch, 0.500 inch, and 0.412 inch diameter cable as-received and after aging for six months (average values).

Brand	Diameter inches	As Received pounds	Aged Six Months pounds
1	0.750	150	95
2	0.750	120	129
3	0.750	12	10.6
1	0.500	80	58
2	0.500	82	75
3	0.500	7.4	4.7
1	0.412	110	110
2	0.412	96	83
3	0.412	15	2.2

TABLE 4

Aluminum shield removal force as a function of time and temperature for Brand 1, 0.500 inch and 0.750 inch diameter CATV Cable (each value average of three tests)

		Aging Temperature (°F)		
		120	140	160
Diameter (Inches)	Time (Minutes)	Aluminum Shield Removal Force (Pounds)		
0.500	15	65	54	29
	60	51	46	15
	240	55	38	10
	960	50	34	8
	1920	51	33	6
0.750	15	77	64	39
	60	65	46	25
	240	63	47	23
	960	61	34	18
	1920	58.5	43	21

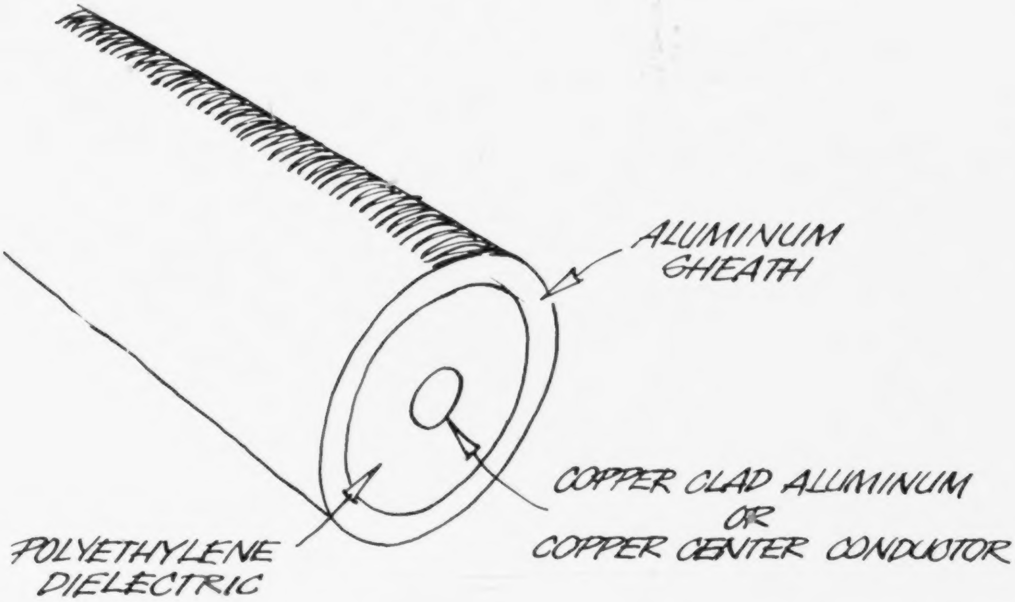

ALUMINUM SHEATH
COPPER CLAD ALUMINUM OR COPPER CENTER CONDUCTOR
POLYETHYLENE DIELECTRIC

Figure 1. Schematic diagram of an aluminum shielded CATV cable with a foamed polyethylene dielectric.

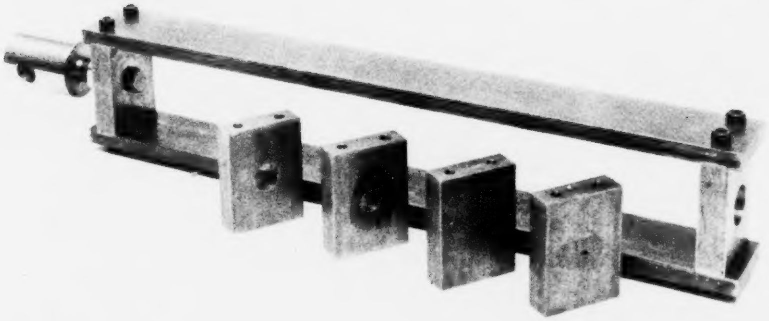


Figure 2 (a) Dielectric adhesion test fixtures

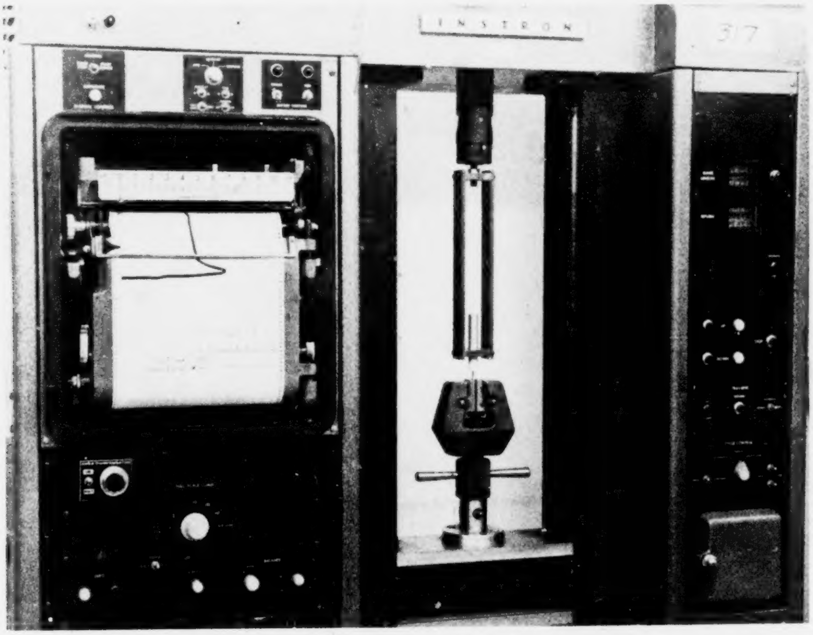


Figure 2 (b) Test fixture and specimen in position on Instron Tensile Testing Machine

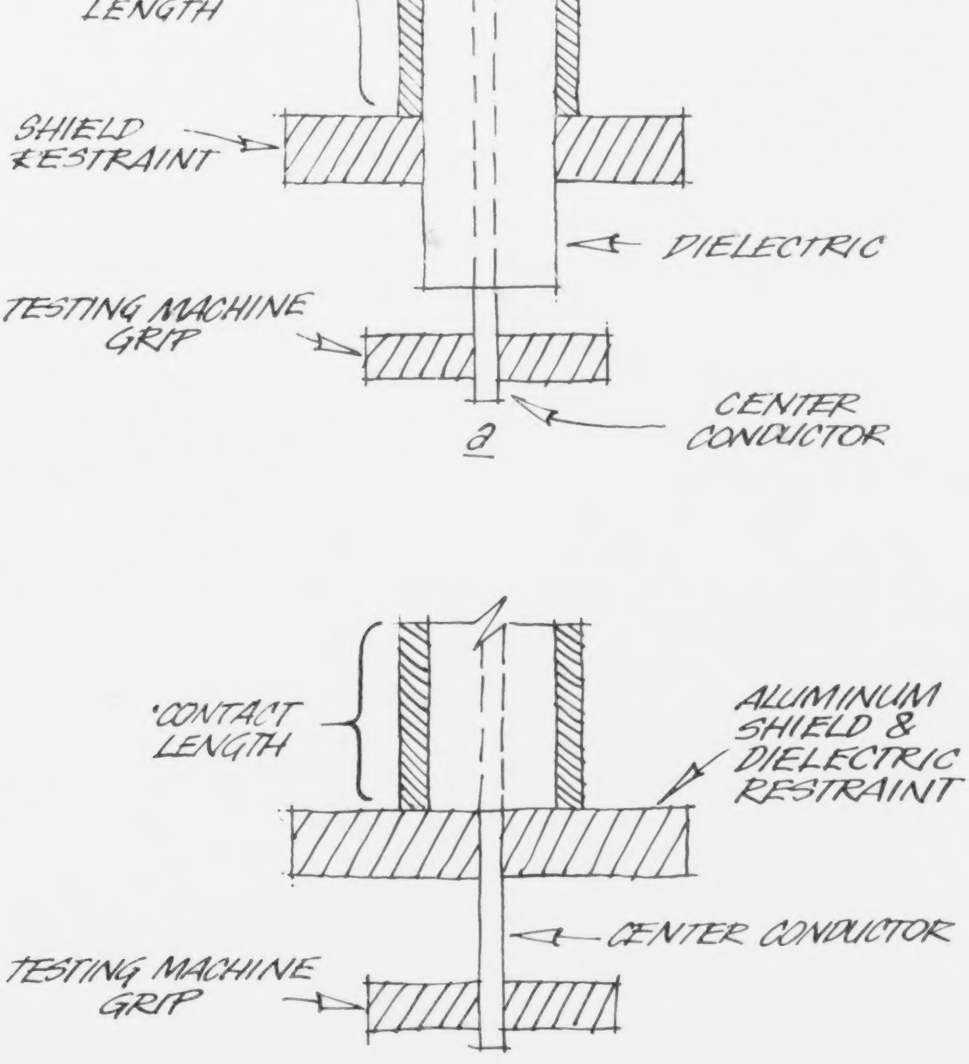

CONTACT LENGTH
ALUMINUM SHIELD
SHIELD RESTRAINT
DIELECTRIC
TESTING MACHINE GRIP
CENTER CONDUCTOR
a
CONTACT LENGTH
ALUMINUM SHIELD & DIELECTRIC RESTRAINT
CENTER CONDUCTOR
TESTING MACHINE GRIP
b

Figure 3. Schematic illustrating the fixture and specimen condition for (a) the shield removal force and (b) the center conductor removal force.

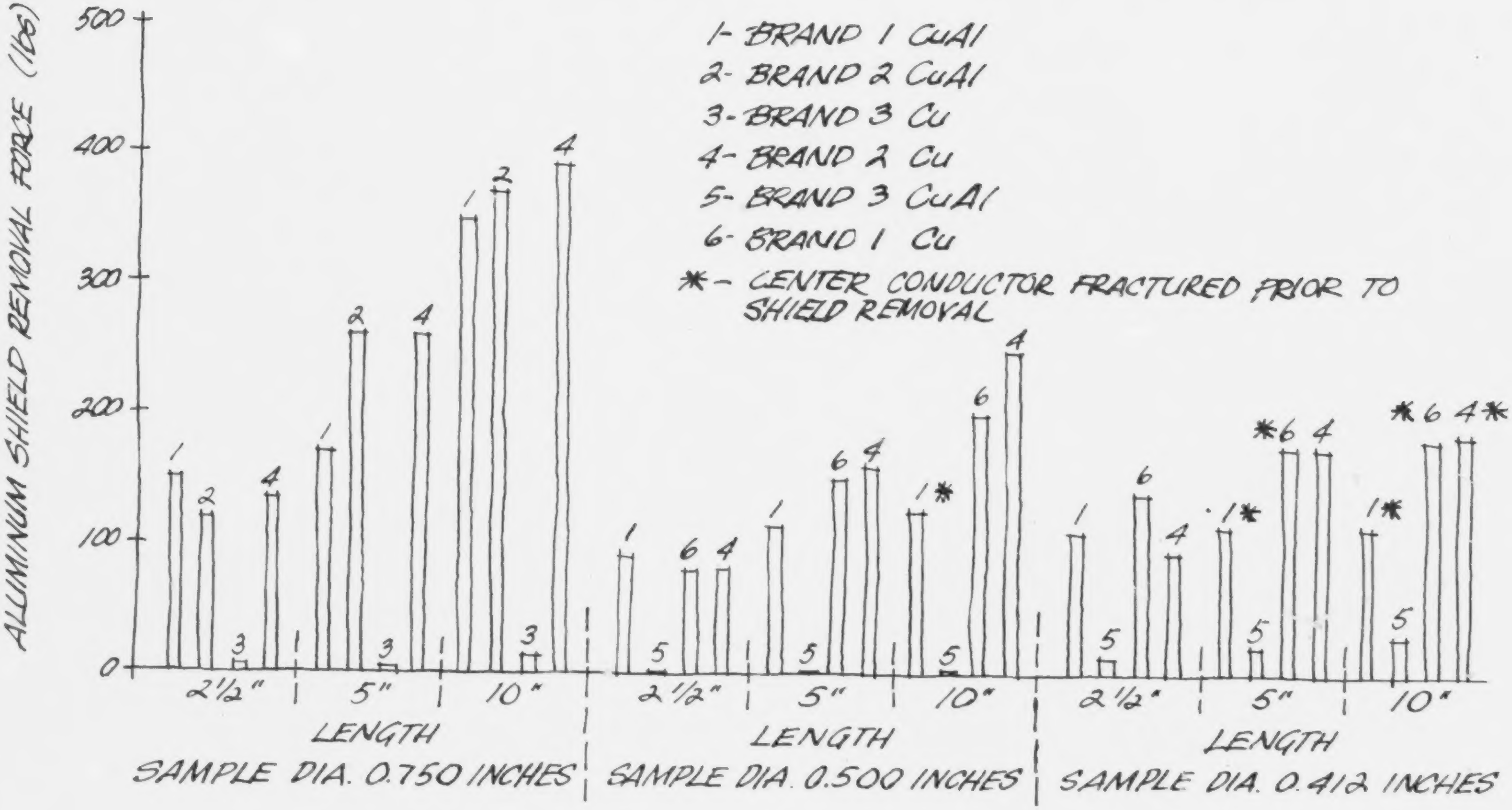


Figure 4. Aluminum shield removal forces for various manufacturers, sample lengths, cable diameters and center conductor materials.

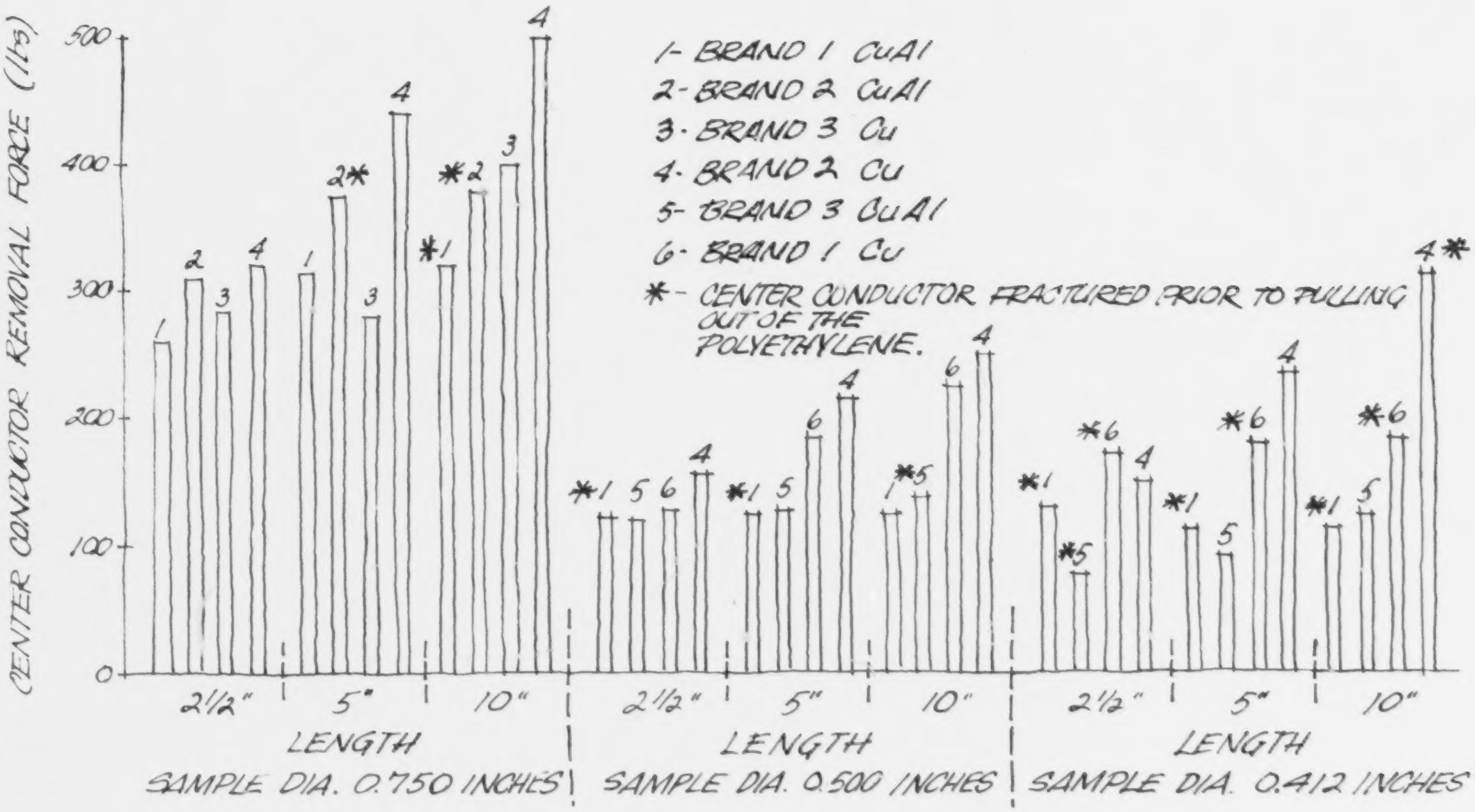


Figure 5. Center conductor removal forces for various manufacturers, sample lengths, cable diameters and center conductor materials.

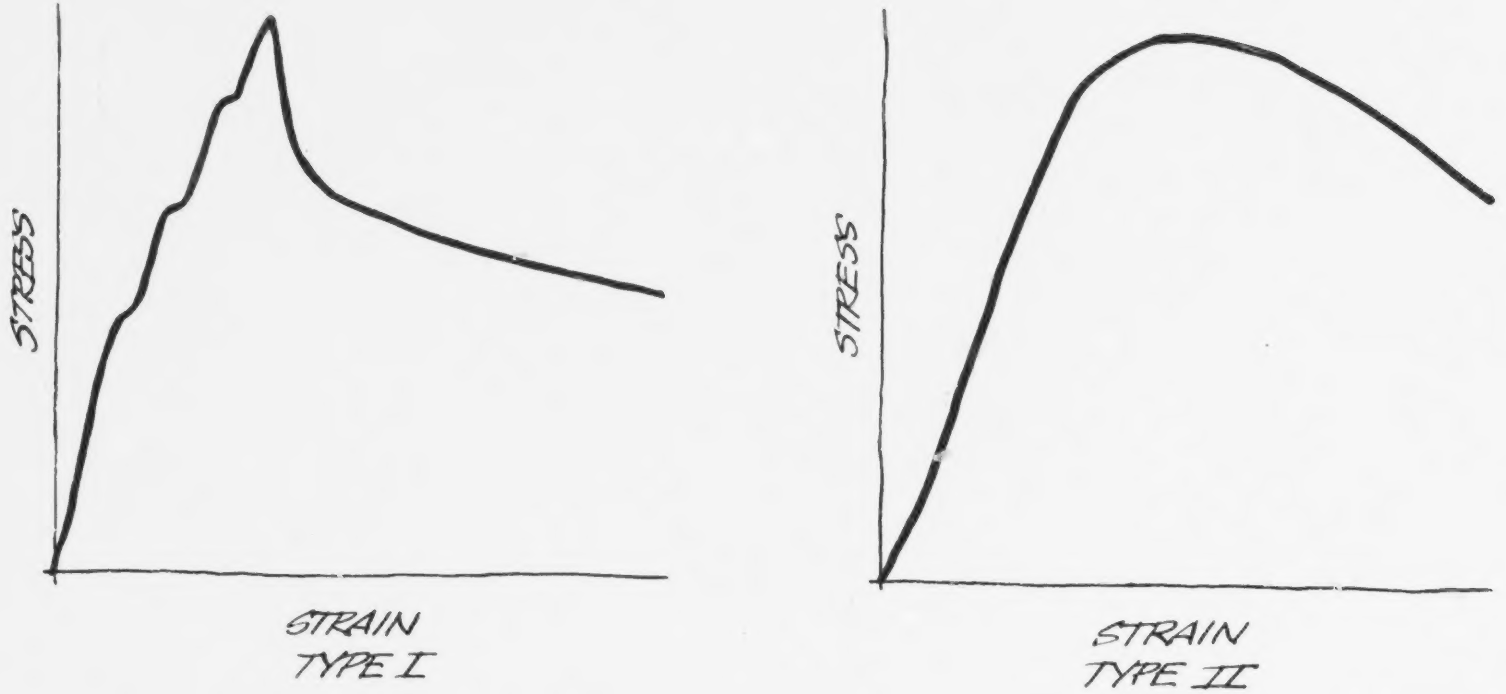


Figure 6. Schematic illustrations of the two typical shapes of a force deflection curve for shield removal and center conductor removal force measurements type.

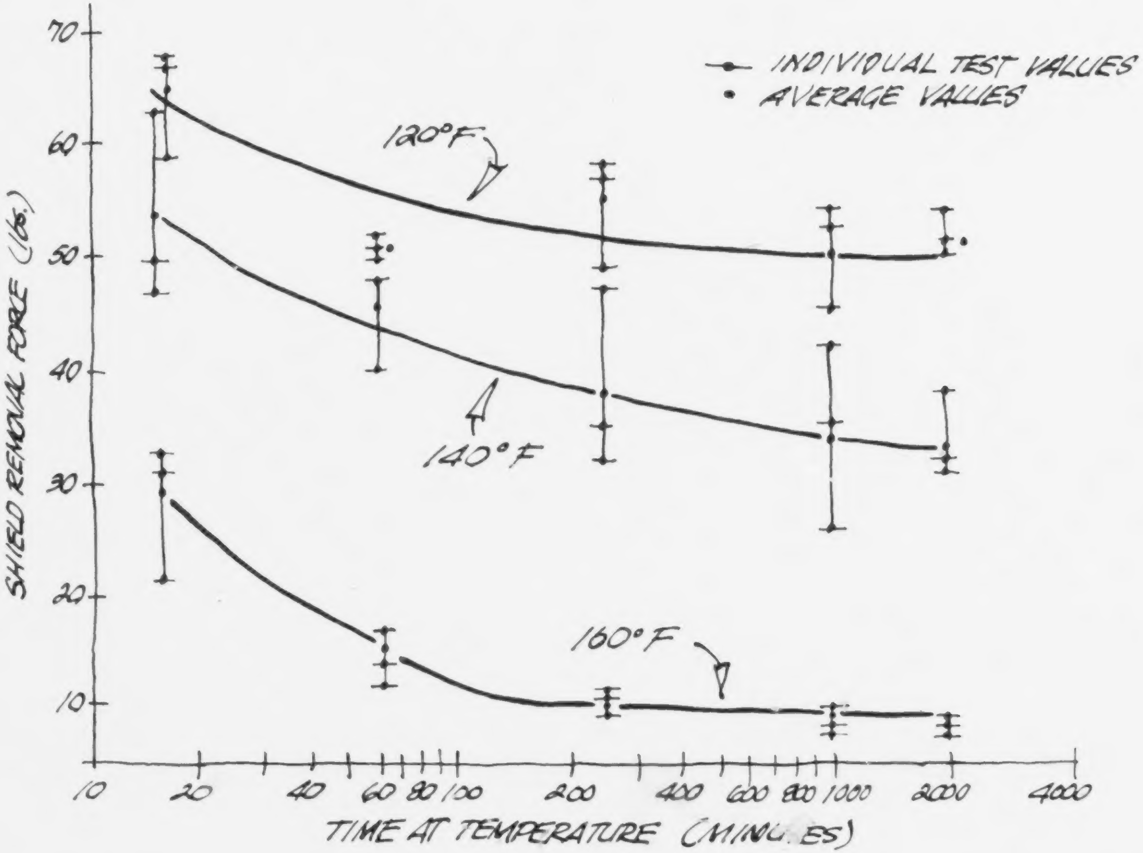


Figure 7. Shield removal forces as a function of time at three temperatures for Brand #1, 0.500 inch diameter CATV cable.

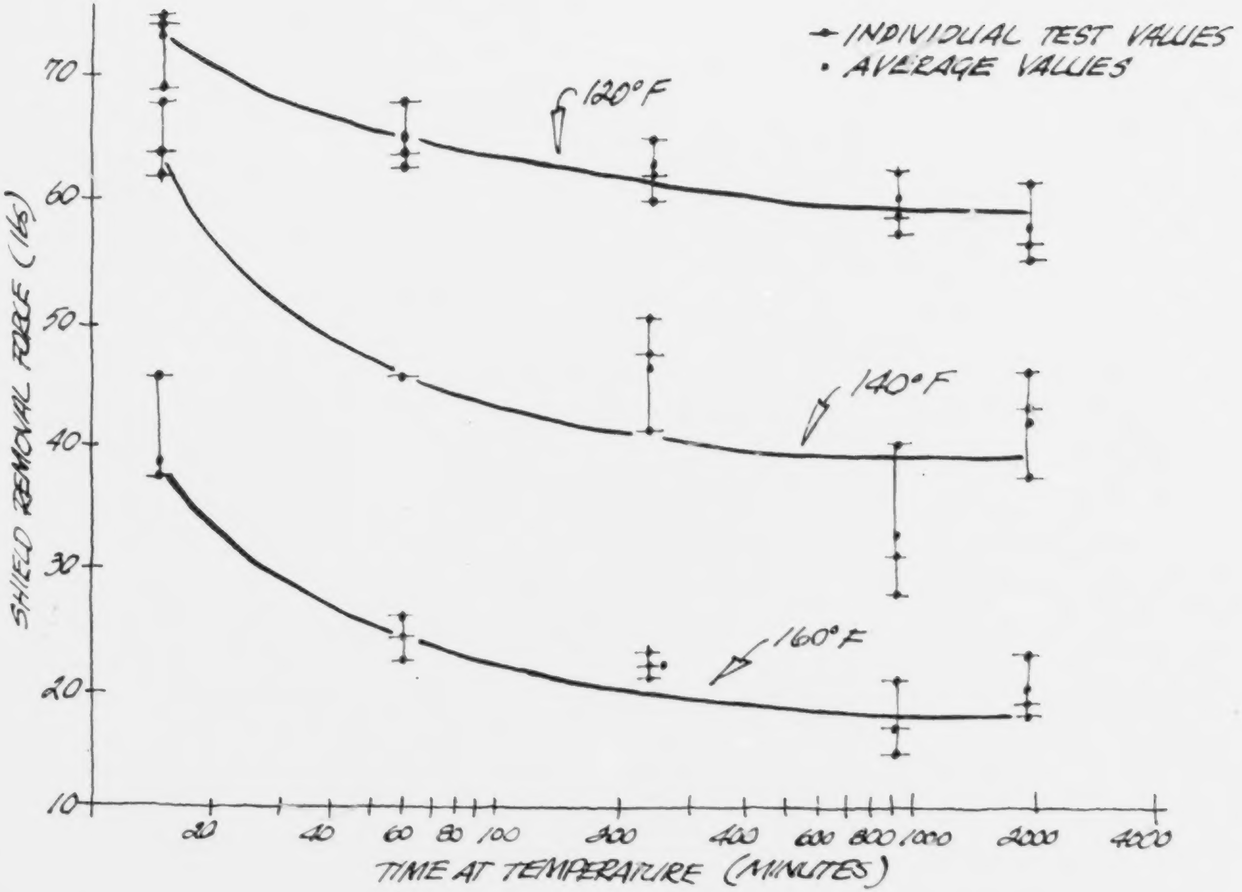


Figure 8. Shield removal force as a function of time at three temperatures for Brand #1 0.750 inch diameter CATV cable.

APPENDIX I

Standard Testing Method for Measuring Shield Removal and Center Conductor Removal Force for a 2-1/2 Inch Contact Length.

Each length of cable to be tested was cut into 4 inch lengths.

Sample preparation was accomplished in a milling machine using a circular saw of 1.750 inches in diameter, two cuts were made in each sample. One transverse cut made through aluminum cladding to establish test length of 2.500 inches. One longitudinal cut was made from transverse cut to end of sample and deep enough to almost reach center conductor. This was done to facilitate removal of aluminum cladding and dielectric material and expose center conductor.

Each sample was inserted in testing frame adapted for use in the Instron Testing Machine.

The parameters used to test samples were:

Crosshead speed -- .5 inch/minute
Chart speed -- 10 inch/minute

Strip chart recording of force and deflection curves were made for all tests and the maximum force value attained designated as the pull out force.

UNDERGROUND COSTS AND INSTALLATION TRADE-OFFS

George R. McGrory
Burnup & Sims Inc.
West Palm Beach, Florida

I'm sure all of us will agree that the most undesirable subject to discuss is how much is it going to cost me to install my facilities. And what am I going to get in return for these costs?

As you know, there are two types of construction that you can use to install your facilities - Aerial and Underground. Aerial involves the associated cost of pole rental rates, as well as make-ready costs. I am sure that you are all familiar with these costs, and realize that they are continuing to increase steadily. The other method is placing your facilities below ground. When we mention the placing of your facilities underground -- we all seem to shudder. We say we cannot afford to do this type of installation, as the costs are extremely high. Let's examine that statement!

Let's look at some of the reasons why underground installations are increasing in the communication industry. The public is getting disturbed by the unsightly pole lines and the miles and miles of wire. This is causing the public to become insistent for underground installations. Today, better public relations are created by placing your facilities underground. You're the "good guy." Also on the plus side, you will reduce possible damage to your facilities from storms -- such as ice and snow in the north, hurricanes and tornadoes in other parts of the country. You also have a more stable facility, due to the constant temperature range found below ground as compared with the variances encountered in an aerial installation.

We are seeing something else, too -- the local governmental agencies are beginning to insist that all new construction be placed underground.

Of course, with any change, there are certain disadvantages. There are some unknown costs that must be considered on any underground installation, such as locating existing underground facilities of other companies. To name a few -- Power, Telephone, Sanitary, Gas and Water. We must know where they are located in order to eliminate any damage to them while installing our underground services. If there is damage, the repairs can be excessive. In a narrow easement where the other facilities are already in place, we may not be able to use trenching or plowing equipment to place your facilities. This means that the trench must be dug by hand in many cases.

Pre-planning your installation will save you many dollars on your underground construction. Let's now analyze what goes into your pre-planning of going underground. Proper planning the path or route of your installation is one big item. Should your facilities be placed in a rear easement or must they be placed in the front or street side? If they can be placed in a rear easement, you can then serve more houses on both sides of the easement, and also you won't have as many streets, driveways or sidewalks to cross under as compared to a front line installation. Regardless of which method you choose, you will still be placing your facilities under streets, driveways and sidewalks. You will be required in most cases to bore or jack and place a pipe or casing under them. This is one item that can be most costly to you.

Some other items involved in underground CATV construction are as follows:

1. Remove and restore sod.
2. Open trench and install cable.
3. Place pledestals and vaults.
4. Install electronic devices.

With this in mind, using a hypothetical case, let's explore the labor costs for a typical normal installation -- and to keep it as simple as possible, let's use for our cost basis a typical city block with a house on each lot, and each lot 75 feet wide. First, we will place your facilities using the direct burial method in the rear easement. By placing this cable in the rear easement, (see Exhibit A) we will have to remove and restore 610 feet of sod. We will place and splice 650 feet of cable and place 4 pedestal terminals. Let's also use one street crossing that we will have to bore or jack under to serve this easement, and make this 40 feet wide. The total cost for this rear easement installation, for the purpose of illustration, will be $600.

Now -- let's take the same city block and move out to the front or street side (see Exhibit B). Again, we will place the cable using the direct burial method. We will also place and splice the same amount of cable -- 650 feet, and place 4 pedestal terminals. But now, we will only remove and restore 482 feet of sod. You will note that the total feet of sod has decreased -- Why? This is due to our boring or jacking under one driveway at each house lot with an average width of 16 feet or for a total number of 128 feet of boring or jacking. We will also be boring or jacking under the same street to serve this run as we did for the rear easement, which was 40 feet wide. The total cost of this front or street side direct burial installation will be $1,000, which is $400 more than for the rear easement installation.

Let's consider another thing, and that is how are you going to serve your customers on the other side of the street? One method which you could use would be to bore and jack under or cut the street at every other lot line in order to serve your customers. Or, you could duplicate the system on the other side of the street. For boring and jacking or cutting at every other lot line (see Exhibit C the additional cost for the city block would be $300, assuming the average street was 20 feet wide. For placing a duplicate system (see Exhibit D), your costs would double, which means an additional cost of $1,000 for the city block. You would be placing double plant footage. Rather than placing a 100 mile system using rear easements, you would actually be placing a 200 mile system if you went entirely on the front or street side.

Now, let's consider again both installations, but instead of placing your facilities by direct burial method, let's place them in conduit. For ease of comparison, we will use one mile as our measuring unit, which comprises 8 city blocks. All your costs will vary depending upon the type of installation that you make, and the type of conduit that you use. Assuming this, then your labor cost for a mile of direct burial facilities in the back easement will be $4,800 per mile, or said more easily $600 times 8 blocks. In the front, or street side, direct burial installation will cost you $8,000 per mile. The labor cost for back easement facilities using conduit will be $6,000 per mile, and the front or street side installation using conduit will be $9,400 per mile.

Logically, looking at pure initial labor costs alone, you would say the best method would be rear easement without conduit. However, we must always look at the future. With the fast changes that are taking place in our industry today -- and changes that are going to take place in the future, such as:

1. Increased bandwidth capabilities;
2. System redesign for dual plant capacity;
3. Increased labor and maintenance costs;

the obvious is not always the most economical. You, the operator, must decide what type of installation you want and how many dollars you care to spend -- however, proper planning and scheduling will help you save many dollars.

In closing, two points to remember when discussing underground installation costs. Choose a reputable CATV contractor who will work in close liaison with the other utilities and knows the inherent problems in going underground. Be sure that he is capable of installing your facilities to your specifications. Make sure that he keeps an accurate set of as-built drawings, because it is the only way you are going to know where your underground facilities are located. Once the trench has been closed, and the grass has completely covered the trench line, no one can tell you where your facilities are located -- not even the person who put them in originally.

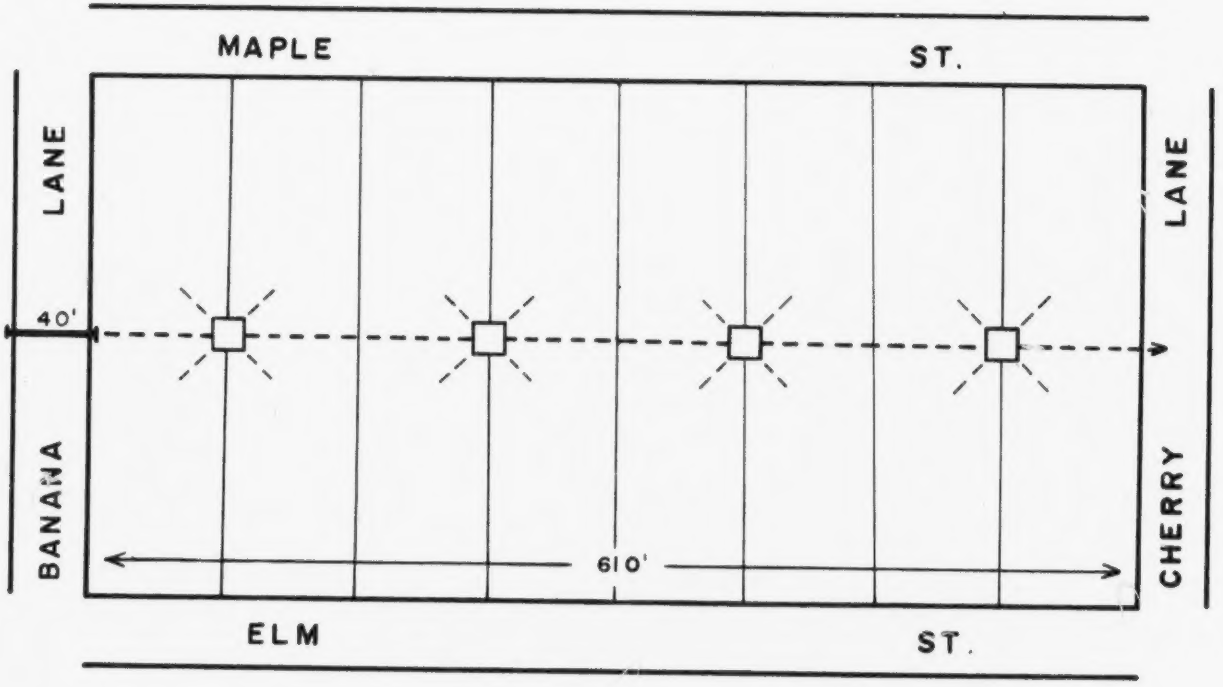
Lastly, don't forget your public image. Let your customer know in advance that you are planning to install underground facilities. Let them know that the contractor will be held responsible for restoring their property to its original condition, and also to their satisfaction. It goes without saying, the job is not complete until the cleanup is finished. And without proper cleanup -- you, the operator can suffer the loss of many of your potential customers which means in turn a loss of expected revenue.

Remember, "out of site -- out of mind -- out of trouble."

It has been my pleasure being here today to discuss the costs of underground installation.

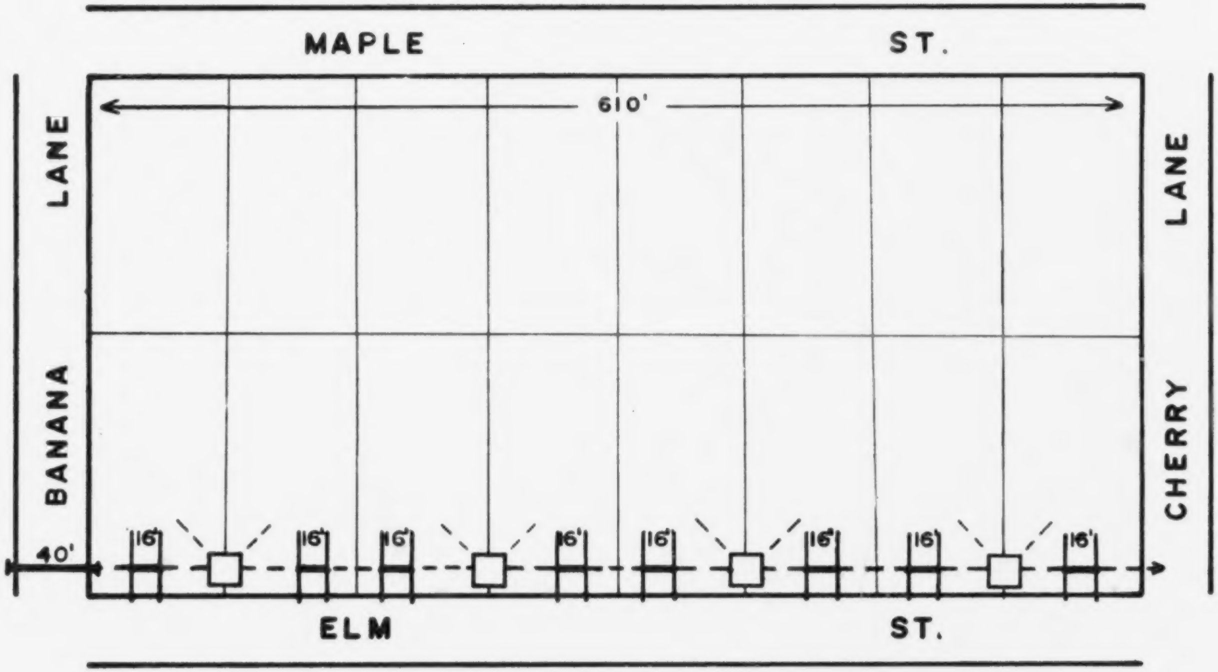
Thank you.

EXHIBIT A


MAPLE
ST.
LANE
BANANA
40'
610'
LANE
CHERRY
ELM
ST.

REAR EASEMENT INSTALLATION

EXHIBIT B


MAPLE ST.
610'
LANE
BANANA
LANE
CHERRY
40'
16'
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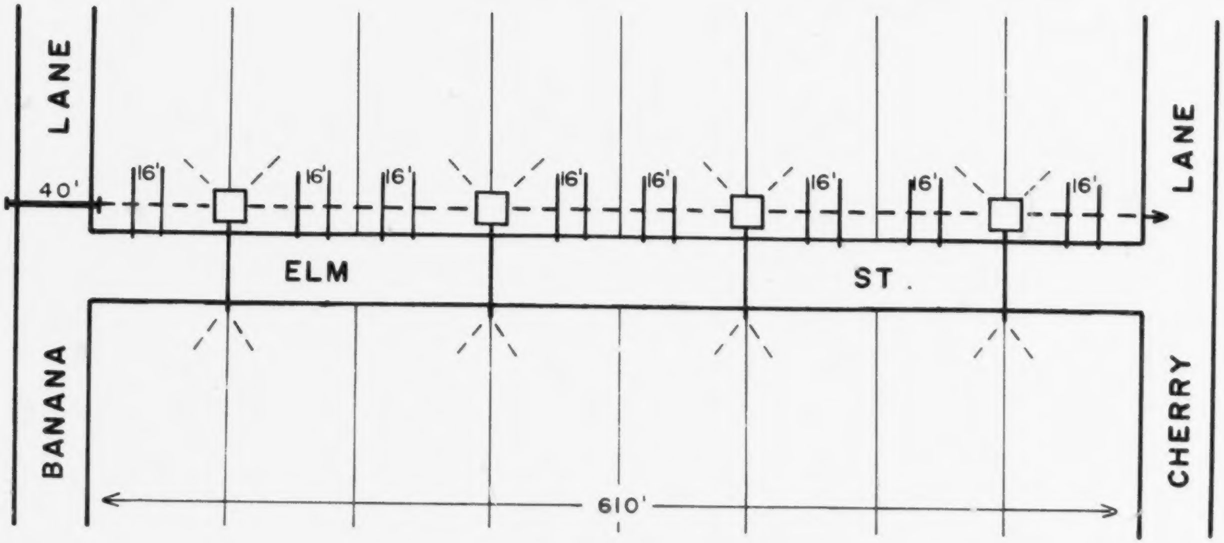
16'
16'
16'
ELM ST.

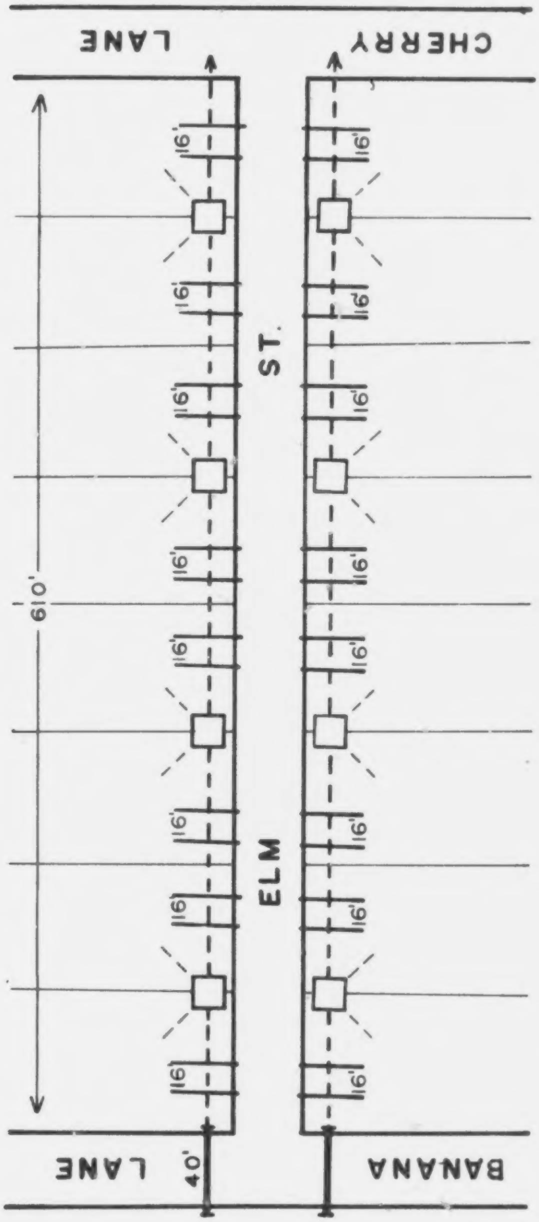
FRONT OR STREETSIDE INSTALLATION

EXHIBIT C


LANE
BANANA
40'
16'
16'
16'
16'
16'
16'
16'
16'
ELM
ST.
LANE
CHERRY
610'

FRONT OR STEETSIDE INSTALLATION –
CASINGS PLACED TO SERVE OPPOSITE SIDE

EXHIBIT D


CHERRY
LANE
BANANA
LANE
ELM
ST.
610'
40'
16'

DUAL FRONT OR STREETSIDE INSTALLATION

RELIABILITY AND MAINTENANCE OF TOTAL UNDERGROUND SYSTEMS

Eugene R. Moon
Vice President and General Manager
Community Cablevision Company
Newport Beach, California

In order to better understand just what the words Reliability and Maintenance mean in relation with a total underground system, let's first consult Webster's Dictionary --

First there's Reliable; "Webster's Dictionary says," Suitable or Fit to be Relied on. (Trustworthy)

Second, there's Maintain; To Hold or Keep in any Condition, esp. in a State of Efficiency or Validity.

From this point we can move towards the way these definations affect the bottom line of our individual Cable TV systems.

To begin with we must start with quality components designed with longivity and ease of maintenance for the consumer in thiscase the CATV Operator.

With the wide choice of phylosophy's, electronic layouts and physical shpaes and sizes this task alone can tend to keep your engineering staff busy for many long tedious hours.

Once the format has been established, long hours of negotiating with the never ending line of equipment brokers and manufactors begins.

Unit price, bulk price, turnkey, MSO discounts, deliver schedules, and financing are some of the language and activities to follow --

At this point a system could be either aerial or underground in the method of construction.

But since the title of this paper "Reliability & Maintenance of Total Underground System" I must begin to align my thought towards this end.

Quality components don't necessarily equate to a quality system. To Build a reliable system, one which can reduce your maintenance cost you must begin with quality components.

I would like to begin by talking about methods and manpower which are important to reliability in your total underground system.

I. Conduit.--Conduit in Underground construction is the most important single item next to waterproofing.

Plan your conduit system so you have space for future expansion. I believe today that most systems who plan on two-way transmissions for the consumer will eventually find more than one cable in their conduits.

Different types of conduit provide different results in the varied earth conditions around the country. Spend some time with the various conduit suppliers, but don't just talk price. Ask about wall strength, couplers, sweeps, and lengths, because once the material is in the ground your stuck with it and all its good and bad points.

Engineer your conduit system so your trunk cable & feeder cable are in separate conduits. This allows for possible replacement with minimum down time for any large segment of your system.

Design your conduit system and install trunk or feeder cable so no splices are located in conduit but in vaults or pedestals.

Daming of conduits in flush vaults is very important since irrigation of greenbelts, parkways always floods vaults at one time or another.

When installing conduits in vaults, duct tape (silver tape) is very cheap compared to the labor involved in cleaning conduits later.

II. Vaults.--Concrete vaults are common in a total underground system and size, location, lids, are very important items to discuss prior to actual construction.

Size is probably the most important item to understand when designing your system because minimum cable bending radius dictates the size, not price - The unit cost for labor is not much different between a #3 and a #5 water meter vault or box.

Location is next in importance because this element in construction effects the maintenance of the system later. Watch for drainage routes which may leave a vault constantly full of water, and make future installs extremly difficult since the vault or box must be drained prior to work commencing.

The location dictates the type of lid required. You should know potential traffic patterns so as not to be required to continualy replace broken lids. The steel fishplate traffic lids in some cases will save money due to constant breakage.

On last item is the care in which vaults or boxes are installed. They should be square with the curb and at a grade commensurate with the surrounding grade or curb. Some areas a coat of green asphalt paint will provide that extra positive public relations we are striving for.

III. Pedestals.--Above ground pedestals are the least expensive protection for active & passive components, but also have some pitfalls.

The most common problem is the condensation action when the pedestal has no free air circulation designed into the design. Past experiences have shown that with an adequate air space between the ground level and the base of the pedestal that no condensation or practically no condensation takes place.

To provide continued protection even in pedestal construction, heat shrink sleeves or tape and coating of liquid neoprene. Above all don't just "think dry construction" but "Practice Dry Construction."

IV. Waterproof Equipment Enclosures.--This section on construction is without a doubt the most single important item relating to reliability and maintenance of total underground systems. For it is waterproofing that will make or break an operator when first getting his feet wet in underground construction.

In the past few years I have been involved in total underground system construction and manage a system with 300 cable miles made up of both above ground and flush types of underground construction. The first cable installed in late 1965, and today expanding by approximately 50 miles each year. We serve one of the "Master Planned Cities of the Future" just outside the 35-mile zone of the second television market in the world, Los Angeles, California. Our potential mileage is 1500 to 2,000 miles by the year 2000. I make mention of these facts to emphasize our dedication to reliable underground system construction. As experienced constructors we rely heavily upon good pedestals and hermetically-sealed enclosures.

Our first exposure to completely flush construction was 1967. The first enclosure used was the Channel Corporation 6-inch plastic hermetically-sealed enclosures which, to this day, have provided 100% security for our splitters, directional taps, and tap-off units. These units or ones which will provide the same protection are a must for the dry equipment required for system reliability.

There is no fear in our operation when it ran because of this method of construction.

In fact the 1971/72 Fiscal Year with a quarterly subscriber count of 3676 . . our system service calls per working day were .95% and on a yearly day average were .83%, and thats with 300 miles of plant in the ground.

The additional cost of the enclosure and labor to install are quickly recaptured by lower maintenance expenses. In fact we have only two system technicians, whose duties include supervision of construction as well as system maintenance.

I have gotten ahead of myself into system maintenance, but the additional information is only ammunition for the point I am trying to make about dry equipment and system reliability.

We also believe in heat-shrink sleeves for all connectors not in hermetically-sealed enclosures, in flush-mounted vaults. In above-ground the use of heat-shrink sleeves can be augmented with self-vulcanizing tape and liquid neoprene if cost is a major factor. But make sure you use one or the other and not a dab of RTV here and there.

There has been no mention of brands or type of electronic equipment because it makes no difference to me what you use, only how you protect it at the time of construction.

Remember only a damm fool walks around all day in the rain in his $35.00 pair of wingtips.

My next topic is maintenance. The mere though of maintenance of a total underground CATV system would almost induce labor pains from a CATV technician who's whole background is in aerial plant maintenance.

Today there are techniques in protecting CATV components such as I mentioned earlier which can make maintenance very easy in underground plant.

The AGC problem is almost solved due to the constant temperatures of cable when installed underground -- no climbing of the telephone poles to repair equipment. The speed in which system balancing can be performed.

The complete removal of pole line attachment agreements a long with repair and maintenance of guy wire, guards, ground rods, and many more items. All these make underground easier to maintain once installed properly.

Commercial power outages are fewer in areas where all utilities are lunderground. But you should seriously consider installation of battery powered standby power supplies. The prime locations are backbone trunk lines where one small power failure can create one very big system outage.

Preventative Maintenance schedules in underground constructed systems are similar to aerial only that it is good procedure and not because there are more problems.

Pressuring backbone trunkline is one of our practices only because our trunk line is so long. We use air dielectric cable and pressurizing is done with nitrogen gas. Our annual nitrogen expense is less than $100.00. Pressure gauges and sectioned areas of cable give us good control over this maintenance chore.

A good selection of test equipment is as essential in underground as it is in aerial systems. A fault locator is like your right arm in locating cable for contractors who plan on digging near your cables.

Other items of importance in the maintenance of underground is in keeping good up-to-date as built prints in case repairs are needed. Complete evaluation of service calls will assit in keeping the pulse of your system in safe zone.

IN SUMMARY - our experiences with a total underground system has proved the reliability and maintenance are strictly in your hands . . . so use them carefully and your new or old underground system will be a success.

HIGHLIGHTS
TECHNICAL SESSION

MULTI-CHANNEL MICROWAVE DISTRIBUTION SYSTEMS

Chairman

Delmer C. Ports
NCTA
Washington, D.C.

Speakers

Douglas D. Milne
Varian/Micro Link
Beverly, Massachusetts

Terry R. Spearen
Microwave Associates, Inc.
Burlington, Massachusetts

Dr. Joseph H. Vogelman
Laser Link Corporation
Woodbury, N.Y.

A. H. Sonnenschein
Theta-Com of California
Los Angeles, California

Reporter

John A. Pranke
Theta-Com CATV
Phoenix, Arizona

1. "The Multipoint Distribution Service - A Threat or a Promise" - Douglas D. Milne

This paper was originally to have been on Varian's new multi-channel CARS equipment, but due to incomplete development, was switched to the subject of Multipoint Distribution Service (MDS). Mr. Milne opened by reviewing the history of microwave transmission of closed circuit television from its first use in the 2500-2700 MHz range for ITFS through to the current MDS service in the 2150 to 2160 MHz band. The present equipment operates in the latter band and employs an omnidirectional transmitting antenna feeding multiple receiving points. The receivers employ parabolic antennas and convert the signals to a VHF channel for feeding a receiver or CATV system over path lengths of up to 20 miles.

MDS is felt to be a complement to CATV since it allows "narrowcasting" special programs to many receiving points and interconnecting these programs into several systems via a receiver at their head-ends.

2. "Multi-Channel CARS Band Distribution Using Standard FM Microwave Equipment" - Terry R. Spearen

Mr. Spearen presented in some detail the calculation of Carrier to Noise Ratio and Video Signal to Noise Ratio for AM Microwave and FM Microwave. In the FM case two deviations were considered: standard 4 MHz and a narrow deviation of 1 MHz. These were then applied to a sample calculation comparing the three cases assuming equal receiver sensitivity. The results showed the standard FM to be approximately 6 dB better than AM, and the narrow deviation FM approximately 6 dB worse than AM.

The conclusion was that standard FM Microwave using separate transmitters had basic advantages over the other methods.

3. "Modulation Index and Transmitter Power Relationship in Multiple Channel TV FM Systems" - Dr. Joseph H. Vogelman

No published paper was available at the session, so Dr. Vogelman spoke directly with the aid of slides. The first portion covered a description of the Laser Link system where the VHF TV signals are combined and treated as a single vector sum signal to modulate the microwave carrier. This was followed by a discussion of the resulting microwave spectrum as the number of channels is changed, and the tradeoffs necessary to keep the sidebands within FCC Specs. As a portion of this, relative comparisons were made between the FM and AM power required for comparable performance. The final portion of the presentation discussed some current work with digitized signals, which offer the possibility for regeneration of the signal and multiple hop applications.

4. "Performance of Multi-Channel Microwave Local Distribution Systems" - A. H. Sonnenschein

Mr. Sonnenschein described the design and operational features of the AML system that takes the VHF output of a conventional head-end and, through a parametric upconverter, produces essentially a single side band AM signal in the 12 GHz CARS band. In the receiver, the VHF signals are recovered by down conversion with the local oscillator phase locked to a pilot tone transmitted with the VHF signals. A detailed description of the test procedures, with illustrations, was given, with emphasis on the fact that these were production tests run on each of the many systems actually operating in the field. Measured test data was also included. In addition, measured test data was presented on AML used to feed a 32 amplifier cascade, which showed that the AML distortion contribution was equivalent to shortening the cascade by 6 amplifiers, but after a 20 mile hop with the AML.

THE "MULTIPOINT DISTRIBUTION SERVICE" A THREAT OR A PROMISE?

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The program originally scheduled for this time slot will not be seen due to technical difficulties completely within our control. While we would very much like to talk about our multi-channel CARS equipment, we are just completing a second generation design, and in light of the broad coverage being devoted to this subject by other speakers later in the schedule, we accepted Del Ports' invitation to switch the topic to the new Multipoint Distribution Service.

This does not mean that we would rather "switch than fight". We definitely favor the AM translator approach to Multichannel TV relay systems and have been using this technique for many years in furnishing 2500 MHz multi-channel systems for the Instructional Television Service.

The new topic — "MDS - A Threat or a Promise" was suggested by Del to acquaint you with the recent FCC action as related to the CATV industry.

First, a little history. In 1963 the FCC established ITFS, the Instructional Television Fixed Service, and allocated 31 TV channels in the 2500-2700 MHz range for use by schools and universities. Varian, along with several other manufacturers, assisted school administrators in applying for Federal Funds to implement innovative systems, and some rather unique installations were accomplished. A typical example is the four channel system used by the Diocese of Brooklyn to transmit instructional programs to over 250 schools. Several multi-channel repeaters are used to provide coverage of the entire Borough. The Brooklyn system and about 100 other systems around the nation represented the first successful application of omnidirectional transmission at microwave frequencies. With an available power output of 10 watts at 2500 MHz (provided by a traveling wave amplifier), omnidirectional antennas having a power gain of 15 dB, and parobolic receiving antennas giving up to 30 dB gain, path losses of about 130 dB or 20 miles could be overcome. Thus, the technology of multi-channel omnidirectional microwave transmission was developed using standard TV format and frequencies, and simply translating or heterodyning to the desired 2500 MHz channels. The receivers, or down-converters (Fig. I) consist of a preselector, a local oscillator and an amplifier covering the high band VHF Channels 7 to 13. Several CATV operators use Varian down-converters at their cable head-end to pick up special school programs or school board meetings televised by the local ITFS studio. The cost for a typical receiving installation is about $1000.

While the 2500 MHz instructional television business was quite active as long as federal funding lasted, it began to dry up and has been very quiet during the last 4 years. As a result, we began looking for other markets for our products. We started by reading the three foot bookshelf known to the trade as the FCC Rules. Anyone who has read these volumes will agree that the plot is rather elusive, but the cast of characters in Washington is quite interesting. When we finally found an obscure reference to omnidirectional transmission at 2 GHz in Part 21, we went to Washington to meet some of the characters and found them most helpful and encouraging. $5,000 later, our lawyers reported progress.

Part 21 is the Bible for those of you who are already common carriers. If the trend towards regulation of CATV continues, more of you may very well become familiar with this Part, in addition to the many controls and regulations that already apply to CATV. The particular paragraph that interested us was 21.703(g) which referred to a bandwidth limitation of 3.5 MHz in the 2150-2160 MHz range. While pretty good monochrome TV can be transmitted in this bandwidth, we really needed at least 6 MHz for color and could use 10 MHz. An exhaustive review tracing FCC actions through several generations finally convinced the Common Carrier Branch that the 3.5 MHz limitation was never really intended to apply to the small segment of spectrum between 2150 and 2160 MHz; so on July 31st, 1970, the FCC released Memorandum Opinion and Order #FCC-70-819 changing paragraph 21.703(g) to permit 10 MHz of authorized bandwidth. The first step towards MDS had been accomplished.

While all this was going on in the Common Carrier Branch, we had also submitted transmitter type acceptance data to the Chief Engineer's Office. The first submittal was for a color TV transmitter at 2150-2160 MHz which required a 6 MHz band. Our application was rejected due to the then effective 3.5 MHz limitation. We therefore modified the transmitter to provide monochrome transmission within a 3.5 MHz bandwidth, and type acceptance was granted. This established the fact that TV could legally be transmitted in the 2150 band, using an omnidirectional antenna pattern. As soon as the 3.5 MHz restriction was removed, we reactivated our type acceptance request for the 6 MHz color transmitter which was promptly granted.

Having progressed to this point, our next step was to probe various groups associated with communications. These groups were the broadcasters, the CATV operators, and the radiotelephone and radio paging operators. We also contacted Ma Bell and Western Union. In time, construction permit applications began to appear at the FCC in sufficient numbers to create a new problem. While the applications were strictly in accordance with the existing Part 21 rules, and while there was no reason why the applications could not be processed in routine fashion, no construction permits were forthcoming. After months of waiting, we found that the common carrier people at the FCC were pretty well buried under some 2000 applications for point-to-point stations for MCI, DATRAN, and a host of operators seeking to compete with Bell. We also found that the MDS applications had been tabled, pending the creation of rules to cover the service. This was a real shocker, as it was obvious that many more months would pass before the new rules could be drafted. To complicate the picture a little more, there was another docket on the books which proposed the use of the 2150-2160 MHz band for aural studio-to-transmitter links.

In spite of all the problems, a few dedicated individuals in the Common Carrier Bureau hammered out a set of rules creating the "Multipoint Distribution Service". This was during mid 1971, and the rumor was that the new rules would be issued "next month". By January 1972, the rumor changed to "next week". On April 19th, 1972 it was reduced to "tomorrow" — and sure enough, Report No. 7686, Docket No. 19493 appeared on April 20th.

While all this was going on within the cloistered walls of the FCC, Washington attorneys and engineering firms were busy preparing applications. The statistics change on a daily basis, but there are now close to 200 construction permit applications on file, and grants are expected next month.

The present MDS applicants represent a cross section of the communications industry, and many are directly or indirectly connected with CATV. Last September Varian invited the existing applicants to a dinner meeting in Washington, and the result was the formation of an industry committee now known as the Multipoint Microwave Common Carrier's Association, MMCCA. In December of 1971, this group presented an "Industry Position Paper" to Commissioner Robert E. Lee, and copies of this comprehensive paper are available from Varian. Optics permitting, I would like to show you portions of the report (attached) and describe the service.

On April 26th the full text of the Commission's "Notice of Proposed Rule Making" for Docket 19493 was issued. This is a 12 page document with many cross references to other rules, and I will not attempt to go into the details. Briefly, it cites the applications on file and states that the requirements of an omnidirectional service differ substantially from those of a fixed point-to-point service — thus the need for new rules, patterned after the 2500 MHz Instructional Television Service.

With this background, let's get to the subject. Is MDS a threat or a promise as viewed by the CATV industry?

As the company responsible for the FCC rule changes which made MDS possible, we sincerely believe it holds a very substantial promise for CATV operators. We further believe that CATV and MDS are complementary services which will benefit by their mutual existence. Our reasons for this belief are as follows: The primary purpose of cable is to reach the home audience. MDS, by its very nature, is not a home type of medium. Ultimately, cable operators expect to have many specialized channels and services available to the home viewer. In fact, the recent FCC action opening more markets to cable television is a major step in the transition and expansion of cable from a mass home audience medium to one also providing a "narrowcasting" or pinpointing service to specialized audiences.

But — before cable can become the dreamboat delivery system of the future, substantial investments of time, effort, and money will be needed — not only to develop the hardware — but more important, to develop the specialized programs and audience demand for these programs. Using cable, this will be a slow process, but MDS can speed the arrival of this day for cable. Through MDS, producers will be able to test the narrowcast concept on specialized business groups. Once this proves successful, it would only be natural to expect that specialized programs would then be distributed via cable into homes or other points served by the system.

MDS and CATV are complementary services for another reason — economics. Just as economics rule out MDS as a home medium, so too will it be ruled out in many other markets. On the other hand, cable will not be competitive in certain markets where MDS will address itself. Cable likes pay dirt and high density areas with a drop every few feet, whereas MDS is a pinpointing type of service to reach widely separated customers. Under these conditions, it is more economical than cable. Clearly, then, by making use of each other's strengths, MDS and CATV can both prosper, with CATV serving the high density residential areas and MDS serving widely separated industrial areas.

Another example would be the use of MDS to transmit special programs to receiving dishes at the head-ends of cable systems, thereby interconnecting several systems without the need to run trunk cables across the countryside. In this situation an MDS common carrier might lease a channel from a cable system operator where signal distribution through the cable would be advantageous to the MDS customer. Thus, MDS would use the cable in those areas where channel capacity is available, and would use the airwaves in those areas not served by cable.

If the FCC wanted to foster the growth of CATV, it could not have picked a better partner than MDS for maximum flexibility and compatability in rendering a complete service.

I hope that this brief discussion has served to dispel any thoughts that MDS is a threat to CATV, and has hopefully served to expose the possible benefits. Several of you are already MDS applicants and there is room for many more, particularly in the areas where CATV found its start.

Thank you for your kind attention, and we will now return to the program originally scheduled for this time!

MULTI-CHANNEL CARS BAND DISTRIBUTION USING STANDARD FM MICROWAVE EQUIPMENT

Presented By

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Introduction

I would like to open this talk with a brief explanation of its title, "Multi-Channel CARS Band Distribution using Standard FM Microwave Equipment". "Multi-Channel" means up to nineteen video channels distributed either on an intercity or intracity basis. "Standard FM Microwave Equipment" refers to broadband single channel FM radio equipment of the type that has been in use for many years, and with which many of you are familiar.

Nineteen Channel CARS Band Distribution

At Microwave Associates, we have developed a technique of carrying nineteen full quality video signals in the CARS Band spectrum from 12.7 to 12.95 GHz, while maintaining the inherent transmission advantages of broadband FM transmission. This has been accomplished by careful control of both the transmitter output power spectrum and the receiver input filtering to produce a transmission characteristic equal to that of the television intercity relays and headend to hub distribution systems that Microwave Associates has been manufacturing for over six years. This equipment is not new in concept and is well proven by the existence of over 600 Microwave Associates systems in use in the United States by television broadcasters, telephone companies, and CATV operators.

What is new about this nineteen channel system is that we are able to produce transmitter output powers of 1/2 watt per channel, which allows multiple power splits for local distribution and adequate power for intercity relay distances. Also, highly stable solid state sources and improved receiver sensitivity allow the very close channel spacing required for the carriage of nineteen channels in the CARS Band.

Standard FM Microwave

My definition of standard FM microwave in this talk is frequency modulated radio equipment in which the fully modulated carrier deviation is 4 MHz peak, or 8 MHz peak-to-peak, and which employs C.C.I.R. 525 line television pre and de-emphasis for improved color video performance.

The purpose of this talk is to compare the video signal-to-noise performance of this system with an amplitude modulated microwave system, and with an FM system employing a carrier frequency deviation significantly less than 4 MHz peak. Of course, there are many other elements that can be compared, but time prohibits full investigation of all aspects of the systems.

Receiver AM Threshold

A basic starting point for signal-to-noise calculations on any radio system is the determination of the receiver AM threshold. By definition, the receiver threshold is the level of the thermal noise generated across the input resistance of the receiver mixer plus the noise generated by the mixer and first preamplifier stage of the receiver.

This chart (Appendix Exhibit 1) illustrated calculation of the AM threshold for a typical microwave receiver.

The formula for AM threshold in dBw (referenced to one watt) is:

$$10 \log_{10} KTBN$$

Where:

B is the receiver RF bandwidth, taken in this example as 15 MHz. It will be shown later that the choice of bandwidth at this point has no effect on the final calculated video signal-to-noise ratio.

K is the Boltzmann's Constant.

T is the thermal noise temperature at the antenna input in degrees Kelvin.

N is the receiver noise figure, which is typically 11 dB at 13 GHz when the insertion loss of the RF filter is included. This noise figure indicates that the receiver input noise is effectively multiplied by 12.9 times due to the imperfection of the receiver mixer and first I.F. pre-amplifier. A perfect receiver, yet to be realized in practice, would have a noise figure of 0 dB.

The solution of this formula indicates that this receiver AM threshold is -121.4 dBw or -91.4 dBm when referenced to one milliwatt. Therefore, any received signal must exceed this level before the receiver can detect its presence in the thermal noise produced by the antenna and the receiver.

The term AM threshold, rather than FM threshold, has been used because the capture effect of an FM receiver tends to reject the received signal until it is above the AM threshold by 9 to 10 dB. This is caused by the peak thermal noise pulses being 9 to 10 dB greater in amplitude than the RMS noise level. Therefore, the detectable received carrier level of an FM receiver is 10 dB less than the same AM receiver. This point is called the FM threshold and is -81.4 dBm in this case. However, this threshold differential is unimportant in video systems because the video signal-to-noise ratio at the FM threshold is so low that the signal is unusable.

AM Carrier to Noise Ratio

The next step in obtaining the video signal-to-noise ratio of the system is the determination of the AM Carrier-to-Noise (C/N) ratio. This ratio is the level of the system received signal level above the AM threshold of the receiver.

To obtain the C/N ratio, the level of the received carrier must first be calculated. This chart (Appendix Exhibit 2) illustrates a typical microwave path calculation under unfaded conditions. The path length has been arbitrarily set at 15 miles. Two six-foot parabolic antennas were selected, and the 1/2 watt transmitter power output produced a received carrier level of -35.3 dBm on the path. This signal level produces a fade margin to FM threshold of 46 dB, which produces very high reliability on a 15 mile path in most areas of the United States.

In this case, our resulting AM carrier-to-noise ratio is equal to +56.1 dB.

Calculation of the Video Signal-to-Noise Ratio from the AM Carrier-to-Noise Ratio

The formula on this chart (Appendix Exhibit 3) is one of the most useful tools available to the system engineer for the evaluation of the signal-to-noise performance of a microwave system. It is from this formula that the video signal-to-noise ratio can be determined when the level of the received carrier above the receiver AM threshold is known.

The formula states that:

$$\text{Video S/N PP/RMS (dB)} = \text{C/N dB} + 10 \log_{10} \frac{\text{BWrf}}{2\text{BW}_m} + 9 \text{ dB} + 10 \log_{10} 3\left(\frac{D}{\text{BW}_m}\right)^2 + \text{Emphasis Improvement (dB)}$$

The constant 9 dB represents the conversion to peak-to-peak/RMS from RMS/RMS.

Emphasis improvement, usually employed only in FM systems, is approximately +2 dB for the standard 525 line C.C.I.R. emphasis. Of course, other systems may employ different emphasis, but I am limiting this comparison to standard FM systems.

The factor $10 \log_{10} \frac{BWrf}{2BW_m}$ (where BWrf is the RF bandwidth used in the calculation of the receiver threshold and BW_m is the video bandwidth of interest) is the bandwidth correction factor which is applicable to both the FM and AM systems. The constant 2 accounts for noise in both sidebands of the detected signal. This bandwidth correction factor eliminates the effect on video signal-to-noise produced by the choice of receiver RF bandwidth as was mentioned earlier. You will note that the selection of a narrower receiver bandwidth will result in a lower AM threshold and corresponding higher AM C/N ratio, but the bandwidth correction factor will decrease proportionately with no resulting difference in the final system video signal-to-noise.

This second factor $10 \log_{10} 3 \left(\frac{D}{BWm} \right)^2$ is the so called FM improvement factor and is one of the most important items in the noise performance comparison of FM ard AM systems. The constant 3 is due to the fact that the broadband noise detected by an FM demodulator has a triangular spectrum. D is the peak deviation of the FM carrier and BWm is the video bandwidth.

Sample Video Signal-to-Noise Calculations

This chart (Appendix Exhibit 4) illustrates the results obtained when the preceding formula is applied to three typical systems. The first is an AM system, the second is a standard FM system with 4 MHz peak deviation, and the third is an FM system where the peak deviation has been reduced to 1 MHz to conserve RF spectrum space.

In the case of the AM system, the solution indicates tha the video signal-to-noise peak-to-peak/RMS equals the C/N ratio plus 11.5 dB.

When the same factors are applied to the standard FM system, the video signal-to-noise will be 17.8 dB greater than the C/N ratio, illustrating that the video signal-to-noise ratio of the standard FM system is over 6 dB better than the equivalent AM system.

However, in the case of the narrow deviation FM system, the signal-to-noise ratio will be approximately 12 dB below the standard FM system and nearly 6 dB below the AM system. As you will note, when the ratio of D to BWm is 0.46, the total FM improvement, including the emphasis improvement, is zero and the system is equivalent in noise performance to an AM system. If this ratio is further, the FM improvement becomes negative at a ratio of $20 \log_{10} \frac{D}{BWm}$, which amounts to -6 dB each time the ratio is reduced by a factor of 2. Obviously, this effect is positive when the ratio is increased, but the sacrifice in RF spectrum does not justify the use of modulation indexes greater than 1 when transmitting broadband video on the system.

Video Signal-to-Noise Ratio versus Receiver Carrier Level In an Operating System

Thus far this talk has been on a somewhat theoretical situation, so this last chart (Appendix Exhibit 5) has been prepared to illustrate the performance of the systems under actual operational conditions.

As we all know, microwave systems are subject to constant and sometimes extreme variations in received carrier level due to atmospheric variables such as rainfall, ducting, etc. Therefore, we are most interested in the performance of the system during these received carrier level variations.

The chart is prepared by determining the C/N ratio for two different received carrier levels, adding the "Improvement" factors to determine the video S/N, and plotting these points on the chart. This is not too difficult since there is a one for one relationship between received carrier level and video signal-to-noise over the useful portion of the curves.

A point of interest on the curves is the non-linearity that occurs at high received carrier levels. This is due to the fact that all active electronic systems have an inherent noise output caused by power supply ripples, component noise, etc. That limits the video signal-to-noise performance of the system. In this case, I have selected a video signal-to-noise ratio of 67 dB as the maximum system limit and all three curves will become tangent to this maximum point regardless of how strong the received carrier becomes.

Another discontinuity illustrated on the chart is the FM Threshold mentioned earlier. Below -81.4 dBm the noise begins to capture the FM system and the video signal-to-noise deteriorates very rapidly.

However, this is not a serious problem because the video signal-to-noise ratio is below the useable level before this received carrier level is reached. This video signal-to-noise ratio is defined as 29 dB PP/RMS flat weighted, and below this point the viewer is expected to give up his TV and listen to the radio.

The curve does indicate that the useable received signal range of the standard FM system exceeds the range of the AM system and the narrow band FM system by the same number of dB that was shown in the earlier calculations. The standard FM system provides then, a higher video signal-to-noise ratio and a greater dynamic signal range than either the AM system or narrow deviation FM system.

Conclusion

I have attempted to describe some of the basic advantages of wideband standard FM microwave radio in a relatively brief period of time. It has not been possible to go to any greater depth of coverage of this subject at this time; however, if further enlargement is desired on any of the formulas or graphs presented this afternoon, please feel free to contact me at Microwave Associates.

APPENDIX

Exhibit 1	Calculation of Receiver AM Threshold
Exhibit 2	Sample Microwave Path Calculation
Exhibit 3	Calculation of Video Signal-to-Noise Ratio from the Calculated Carrier-to-Noise Ratio
Exhibit 4	Sample Calculations
Exhibit 5	Video S/N VS. Receiver Carrier Level
Exhibit 6	Multi-Channel CARS Band System

EXHIBIT 1

CALCULATION OF RECEIVER AM THRESHOLD

AM THRESHOLD

AM Threshold = $10 \log_{10}$ KTBN

Where:

B is the Receiver RF Bandwidth = 15 MHz

K is the Boltzmann's Constant = 1.37×10^{-23} joule/degree Kelvin

T is the noise temperature at the antenna input = 293° Kelvin

N is the Receiver Noise Figure of 12.6 = 11 dB

With the above figure:

$$\begin{aligned} \text{AM Threshold} &= 10 \log_{10} (1.37 \times 10^{-23} \times 293 \times 15 \times 10^{6} \times 12.6) \\ &= 10 \log_{10} (7.24 \times 10^{-13}) \\ &= -121.4 \text{ dBw} \end{aligned}$$

Where:

-121.4 dBw is the receiver thermal noise power relative to one watt. To convert to milliwatts, a more common reference in path calculations, add +30 dB.

Therefore:

The Receiver AM Threshold = -91.4 dBm for an 11 dB receiver Noise Figure and 15 MHz RF Bandwidth.

EXHIBIT 2

SAMPLE MICROWAVE PATH CALCULATION

Operating Frequency 12.825 GHz

Path Length 15 Miles

Losses		
Free Space Path Loss		-142.3 dB
Fixed Losses		
Elliptical Waveguide 40 ft.	-1.8 dB	
Branching (Typical Multichannel)	-4.0 dB	
Antenna Radomes	-2.2 dB	
Misc. (Alignment, etc.)	-2.0 dB	
Total Fixed Losses from above		- 10.0 dB
Total System Losses		-152.3 dB
Gains		
Transmitter Power (0.5 watt)	+27 dBm	
Antennas (2-6' Parabolas at 47 dBi each)	+90 dBm	
Total System Gains		117.0 dB
Received Carrier Level (Sum of Loss plus Gains)		-35.3 dBm

AM Carrier-to-Noise (C/N) Ratio = Received Carrier Level (above) - AM Threshold (From Exhibit 1).

AM C/N Ratio = -35.3 dBm - (-91.4 dBm) = +56.1 dB

EXHIBIT 3

CALCULATION OF VIDEO SIGNAL-TO-NOISE RATIO FROM THE CALCULATED CARRIER-TO-NOISE RATIO

The following formula is employed to derive the video S/N ratio when the AM C/N ratio has been determined.

$$\text{Video S/N (dB)} = \text{C/N dB} + 10 \log_{10} \frac{BWrf}{2BW_m} + 9 \text{ dB} + 10 \log_{10} 3\left(\frac{D}{BW_m}\right)^2 + \text{Emphasis Improvement (dB)}$$

Where:

C/N = AM Carrier-to-Noise Ratio = Level of the received carrier above the receiver AM Threshold (Exhibit 2).

$10 \log_{10} \frac{BWrf}{2BW_m}$ is the AM and FM bandwidth correction factor.

9 dB is the conversion to peak-to-peak/RMS from RMS/RMS video S/N.

$10 \log_{10} 3\left(\frac{D}{BW_m}\right)^2$ is the FM Improvement Factor.

Emphasis improvement is normally +2 dB for standard 525 line C.C.I.R. emphasis.

BWrf is the system RF bandwidth used in the calculation of the receiver AM Threshold (15 MHz).

BW_m is the bandwidth of the modulating signal which is normally 4.2 MHz for video.

D is the peak deviation of the FM carrier, which is 4 MHz in the standard FM system.

EXHIBIT 4

SAMPLE CALCULATIONS

1. For an AM System

$$\text{Video S/N PP/RMS} = C/N + 10 \log \frac{BWrf}{2BW_m} + 9\ \text{dB}$$

$$= C/N + 10 \log \frac{15\text{x}10^6}{2\text{x}4.2\text{x}10^6} + 9\ \text{dB}$$

$$= C/N + 2.5\ \text{dB} + 9\ \text{dB}$$

$$= C/N + 11.5\ \text{dB}$$

2. For the Standard FM System

$$\text{Video S/N} = C/N + 11.5\ \text{dB (from above)} + 10 \log_{10} 3\left(\frac{D}{Bm}\right)^2 + 2\ \text{dB}$$

$$= C/N + 11.5\ \text{dB} + 10 \log_{10} 3 \left(\frac{4}{4.2}\right)^2 + 2\ \text{dB}$$

$$= C/N + 11.5\ \text{dB} + 4.3\ \text{dB} + 2\ \text{dB}$$

$$= C/N + 17.8\ \text{dB}$$

Therefore, the Standard FM System provides a 6.3 dB Video S/N advantage above the equivalent AM System.

3. As a comparison, the following calculation illustrates the effect on FM improvement when the peak deviation of the FM carrier is reduced to 1 MHz to conserve RF spectrum:

$$\text{Video S/N PP/RMS} = C/N + 11.5\ \text{dB} + 10 \log_{10} 3\left(\frac{1}{4.2}\right)^2 + 2\ \text{dB}$$

$$= C/N + 11.5\ \text{dB} + (-7.6\ \text{dB}) + 2\ \text{dB}$$

$$= C/N + 5.9\ \text{dB}$$

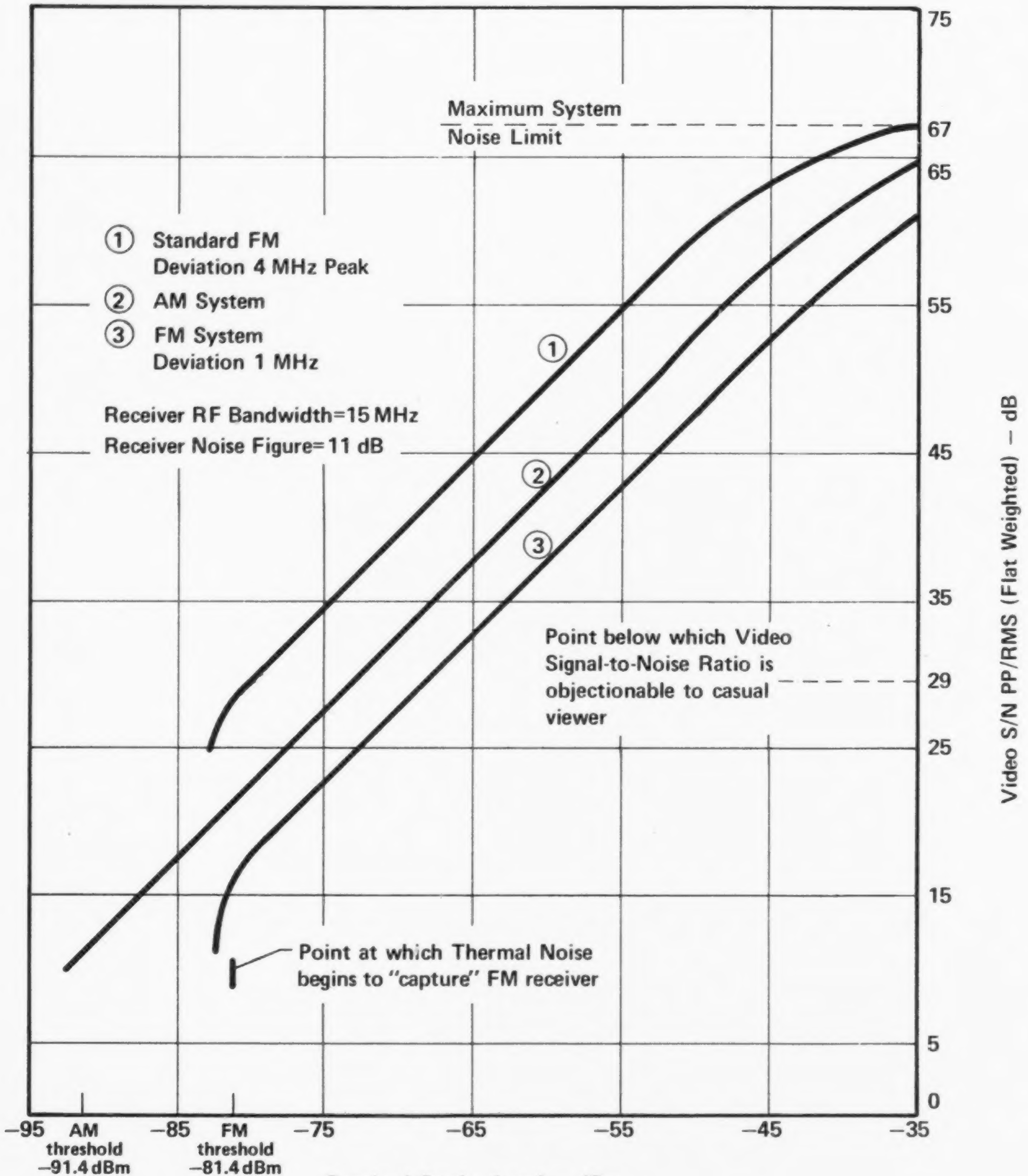

EXHIBIT 5 VIDEO S/N VS. RECEIVED CARRIER LEVEL

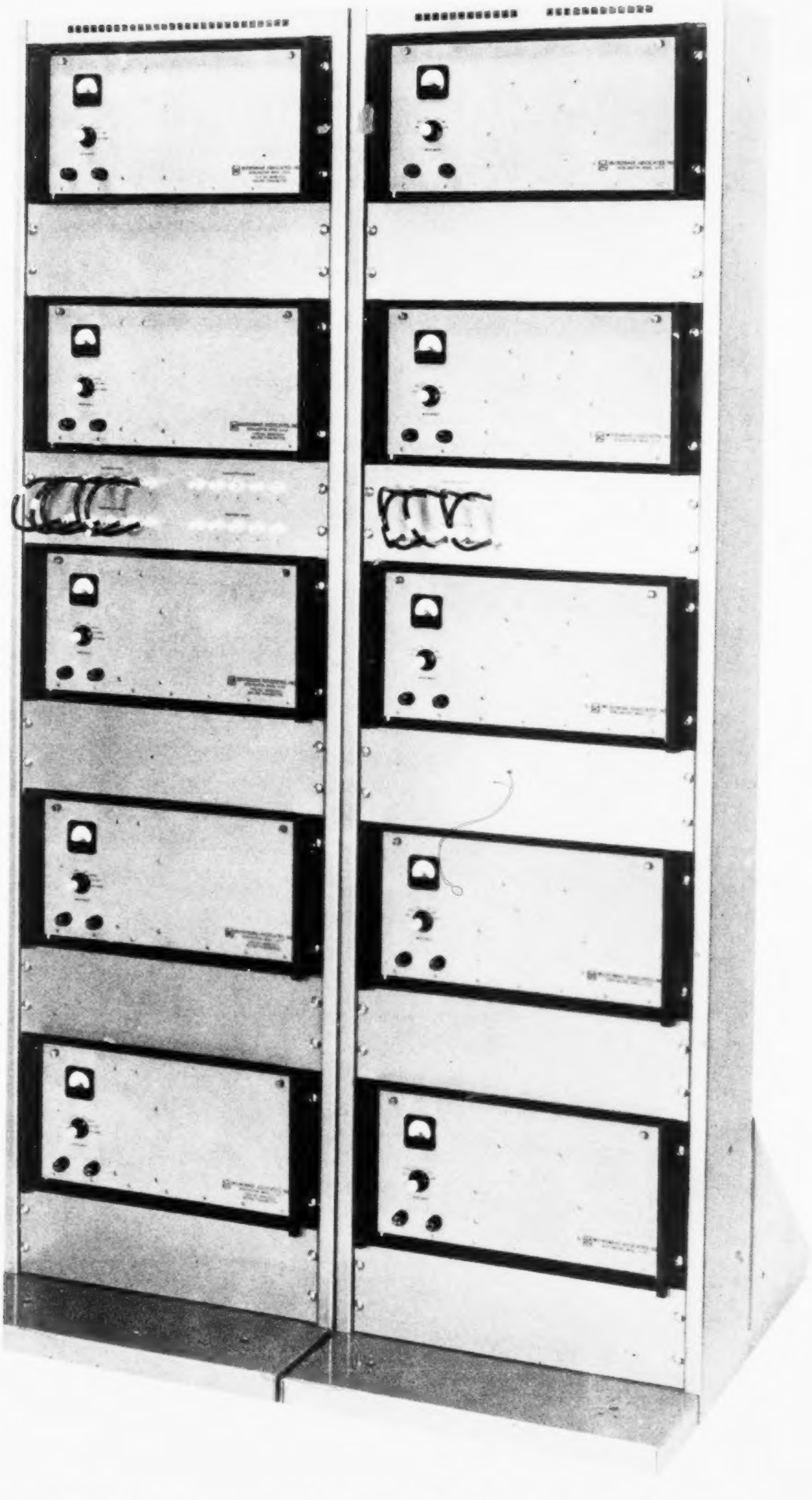

Exhibit 6. MULTICHANNEL CAR BAND SYSTEM

MODULATION INDEX AND TRANSMITTER POWER RELATIONSHIP IN MULTIPLE CHANNEL FM SYSTEMS

By Dr. Joseph J. Vogelman, Chief Operating Officer, & Malcolm Reader, Director of Engineering, Laser Link Corp.

In a recent paper titled "Understanding Laser Link's FDM/FM Airlink System", appearing in this month's issue of Cable News (copies available on request from Laser Link Corp.), the authors reviewed the operation of frequency division multiplexed FM systems. A point was made of the fact that the FM system superposes the various subcarriers and behaves as each one existed alone in its part of the output spectrum. This corresponds to the experience of many engineers who have tested a visual carrier for SNR and an aural carrier for SNR on a single TV channel FM microwave system and have observed that the signal to noise ratios of the individual carriers are independent of the presence of absence of the other subcarriers. By the same process of superposition, it is possible to determine the effective spread of energy from the carrier to the sidebands when many television channels are combined by frequency division multiplex (see figures 1 and 2) and then impressed as a modulation drive on an FM system. In all FM systems, the concept of energy left in the carrier as opposed to energy in the sidebands must be dealt with using one precaution. Recalling that an AM system, under conditions of increasing modulation, shows increasing energy delivered to the sidebands, until 100% of modulation is reached, the communications engineer is careful to avoid further drive because this will result in overmodulation and distortion of information. 100% modulation in AM corresponds to 50% of energy in the carrier, and 50% of energy in the sidebands. If one sideband is fully suppressed, 66% of the energy is left in the carrier, and 33% is in the unsuppressed sideband. As a practical matter, suppressed sideband television with average picture content, and with the FCC standard for 0.75 mhz of the suppressed sideband still carried on the air, 46% (sideband energy)- 54% (carrier energy) relationship is typical. With FM, there is no corresponding physical limitation on the depth of modulation, other than the quality of the FM equipment, and the limitations of **spectrums** spread imposed by legal use of bandwidth. Thus with FM systems, equal effective use of power as compared with a 100% modulated AM carrier corresponds to a modulation index of approximately 1.00 (see references 1 and 2). However, the FM system can be driven harder and harder into modulation, and at modulation index of 2.403, 100% of the energy is then in the sidebands. Further drive is quite practical with a linear FM system, producing well known the condition of improvements of signal to noise ratio with greater modulation indexes. Under these conditions, the ratio of energy in sidebands to energy in carrier grows poorer, that is to say the carrier then shows an increasing percentage of power at the expense of energy in the sidebands, while signal to noise ratio is increasing. Therefore to use the analogy of energy in sidebands as an indicator of useful distribution of energy, one must confine the area of interest to values of modulation index below 2.403. Above that value of modulation index, the analogy can be extended by using the effective power in sidebands, and referring to them as more than 100%. Thus with a modulation index 2.93 one can refer to the energy in the sidebands as being effectively 150%.

As indicated above, the multichannel FM system can be analyzed as if each subcarrier (channel) existed separately. Therefore one can take each information channel (TV channel in our case) and determine how much energy exists in the sideband as a result of its individual depth of modulation. Typical spectrum analysis photos of spectrum content of Laser Link's multi-channel FM transmitter are shown in figures 3-6. In the airlink system, no individual channel has a modulation index that exceeds 2.403 so that the energy in the sidebands due to that channel alone can be determined by reference to a table of bessel function that shows the drop in carrier power at each channel modulation index. The remaining power is in the sidebands. Then by adding the power in the sidebands due to each of the individual channels, the effective total of energy in the sidebands can be found. Where this energy is less than 100%, this is the total sideband energy, and an effective overall modulation index corresponding to this can be computed. Where the effective sideband energy is more than 100%, then the effective overall modulation index can be computed corresponding to modulation of more than 2.403.

The above computations have been performed for the Airlink System in tables 1 thru 11, for 5 thru 18 channels of television on a single Airlink system. The results of these tables have been summarized on table 12. This shows that with the poorest modulation indexes used (limitations of bandwidth under F. C. C. Rules and Regulations), the modulation index is 0.96 corresponding to the same effective use of power as an AM system. However, being a single channel FM system, as much as 60 watts of power is available for use at a single transmitter location. In the case of higher modulation indexes, as much as 3.59 improvement is available over the corresponding AM system on the basis of watt for watt equivalence. This is more than 10 db of improvement of a watt for watt equivalence for AM.

Another method for determining the effective power of an FDM/FM transmitter in terms of modulation index is to set up an equivalence relationship between power required for individual AM channels to produce the same SNR as the channels of an FDM/FM system. By adding all the individual AM powers required, one gets the total AM transmitter power needed for equivalence. The FM channels all use the same transmitter power, as indicated above, so that a direct comparison is possible, on the basis of identical paths, identical antenna gains and identical waveguide sections. The derivation that is given below uses the terms "A", "B", "C", and "D" to represent air path, antenna and waveguide. Since these are indentical for AM and FM systems, they cancel in the comparison, making the relationship general for all cases.

Ref. 1 ITT Radio Engineers Handbook 21-12.

Ref. 2 Mischa Schwartz, Information Transmission, Modulation and Noise, page 305, McGraw Hill and Company, 1959.

AM System
- .X milliwatts=x dBm for an individual TV channel delivered to an antenna feed.
- .5MHZ bandwidth/Channel
- .Noise figure 12dB
- .Path loss "A" dB
- .Transmitter antenna gain "B" dB
- .Receiver antenna gain "C" dB
- .Incidental waveguide and fitting losses "D" dB
- .Modulation 100%

Carrier power at receiver=x-A-D+B+C dBm
Receiver channel noise power in 5MHZ=10 $\text{Log}_{10} \frac{5}{1}$ = 7dB

Noise power of receiver= -114+12+7= -95dBm
Channel carrier to noise ratio=x-A-D+B+C- (-95)
Channel signal to noise ratio= 95+x-A-D+B+C

If AM and FM system have same SNR

$95+x-A-D+B+C=136-A-D+B+C+p$
$95 + x-136=P$
$x-41=p=10\ \text{Log}_{10}(M)^2 = 10\ \text{Log}_{10} X-41$

$-41= 10\ \text{Log}_{10} \frac{1}{12600}$ $\quad X=12600\ M^2$

This is a relationship between power per AM channel to channel modulation. Index for equal signal to noise ratio.

The relationship $X=12600M^2$ is plotted as a curve in Figure 7.

The comparison for airlink systems of 5 to 18 channels, operating at the modulation indexes of tables 1 thru 11 is given as table 13. As can be seen, the equivalent AM system would require transmitted power of 10.38 to 89.00 watts.

Equivalent AM Power Computation

FM System Conditions
- .20 watts of power=+43 dBm
- .250 MHZ bandwidth
- .Noise figure 12dB
- .Path loss "A" dB
- .Transmitter antenna gain "B" dB
- .Receiver antenna gain "C" dB
- .Incidental waveguide and fitting losses "D" dB
- .Channel modulation Index=M

Computation:

Carrier power at Receiver= 43-A-D+B+C dBm

Noise power in 250 MHZ=10 $\text{Log}_{10}\frac{250}{1}$ = 24 dB above 1 MHZ

Noise power of receiver= -114+12+24= -78 dBm

Receiver carrier to noise ratio= 43-A-D+B+C- (-78)
= 43+78-A-D+B+C
= 121-A-D+B+C

Video bandwidth per TV channel (2 sidebands)=8MHZ

Noise bandwidth reduction= 10 $\text{Log}_{10}\frac{8}{250}$ =+15dB

Modulation Index (referred to 1.00) as a factor in SNR= 10 $\text{Log}_{10}\left(\frac{M}{1}\right)^2$ = p (dB)

Channel signal to noise ratio= 121-A-D+B+C+15+p
= 136-A-D+B+C + p

This presumes a receiver input above the FM threshold of 10 dB above receiver noise figure. In actual practice SNRS are designed to stay above 35dB in worst case conditions, for Airlink systems.

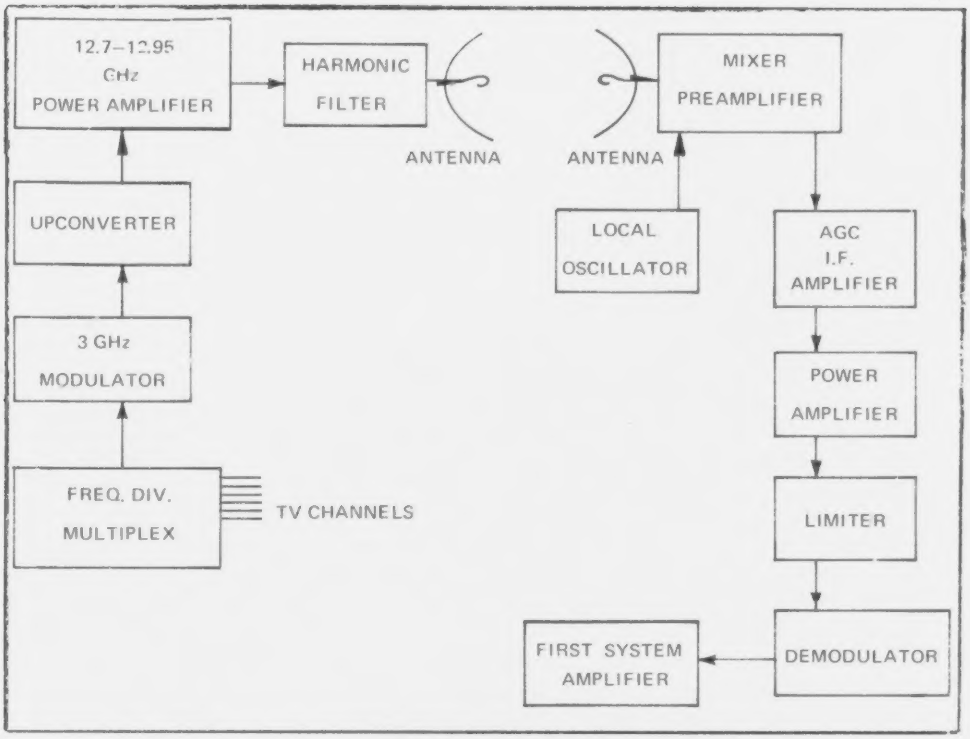
12.7–12.95
GHz
POWER AMPLIFIER
HARMONIC
FILTER
ANTENNA
ANTENNA
MIXER
PREAMPLIFIER
UPCONVERTER
LOCAL
OSCILLATOR
AGC
I.F.
AMPLIFIER
3 GHz
MODULATOR
POWER
AMPLIFIER
FREQ. DIV.
MULTIPLEX
TV CHANNELS
LIMITER
FIRST SYSTEM
AMPLIFIER
DEMODULATOR

FIG. 1 BLOCK DIAGRAM OF LASER LINK AIRLINK SYSTEM

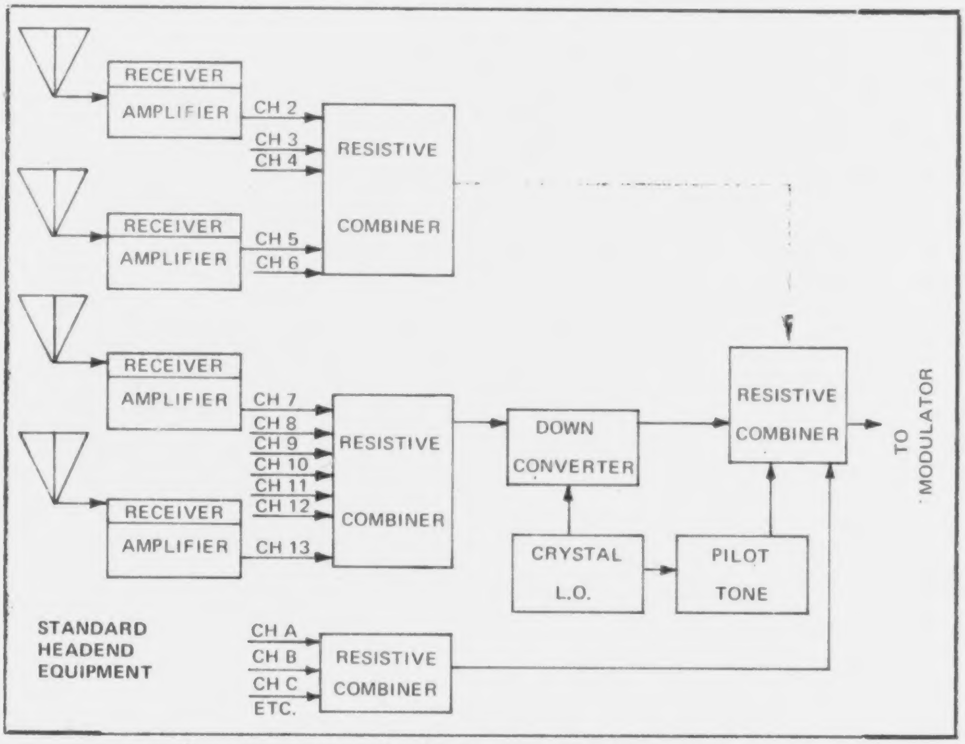
RECEIVER
AMPLIFIER
CH 2
CH 3
CH 4
RESISTIVE
COMBINER
RECEIVER
AMPLIFIER
CH 5
CH 6
RECEIVER
AMPLIFIER
CH 7
CH 8
CH 9
CH 10
CH 11
CH 12
RESISTIVE
COMBINER
RECEIVER
AMPLIFIER
CH 13
DOWN
CONVERTER
RESISTIVE
COMBINER
TO
MODULATOR
CRYSTAL
L.O.
PILOT
TONE
STANDARD
HEADEND
EQUIPMENT
CH A
CH B
CH C
ETC.
RESISTIVE
COMBINER

FIG. 2 FREQUENCY DIVISION MULTIPLEXING OFF THE AIR

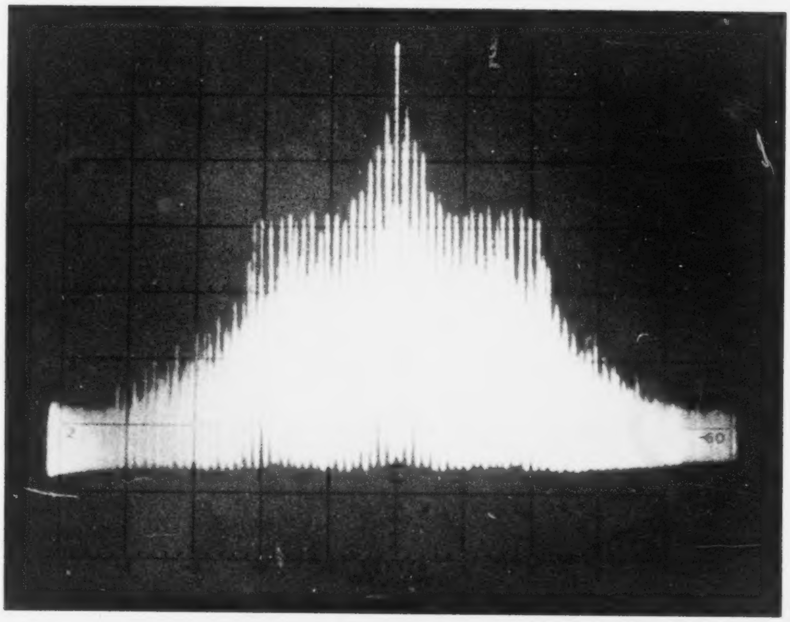

FIG. 3 SPECTRAL CONTENT OF 15 CHANNEL MODULATED AIRLINK TRANSMITTER

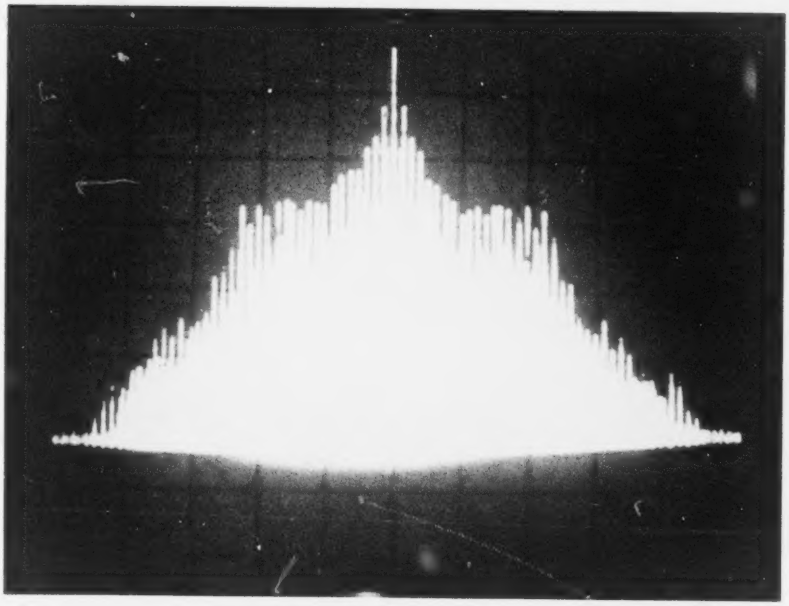

FIG. 4 SPECTRAL CONTENT OF 16 CHANNEL MODULATED AIRLINK TRANSMITTER

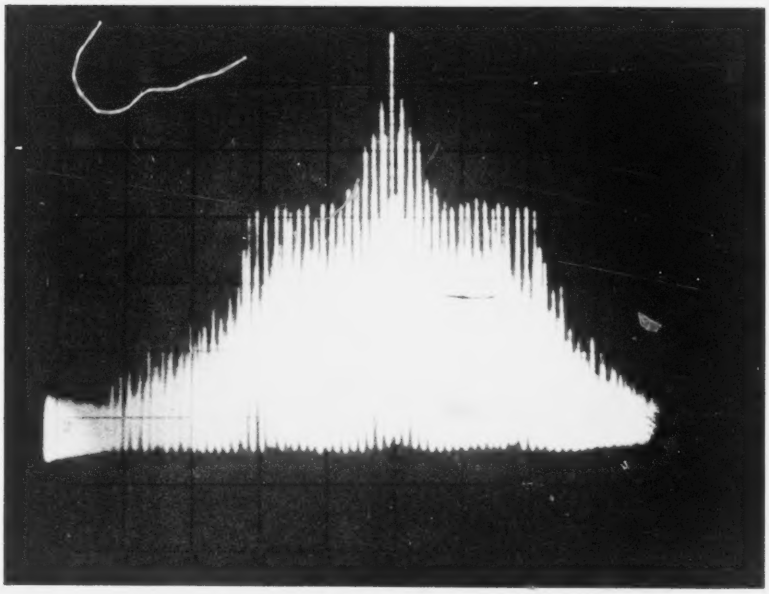

FIG. 5 SPECTRAL CONTENT OF 17 CHANNEL MODULATED AIRLINK TRANSMITTER

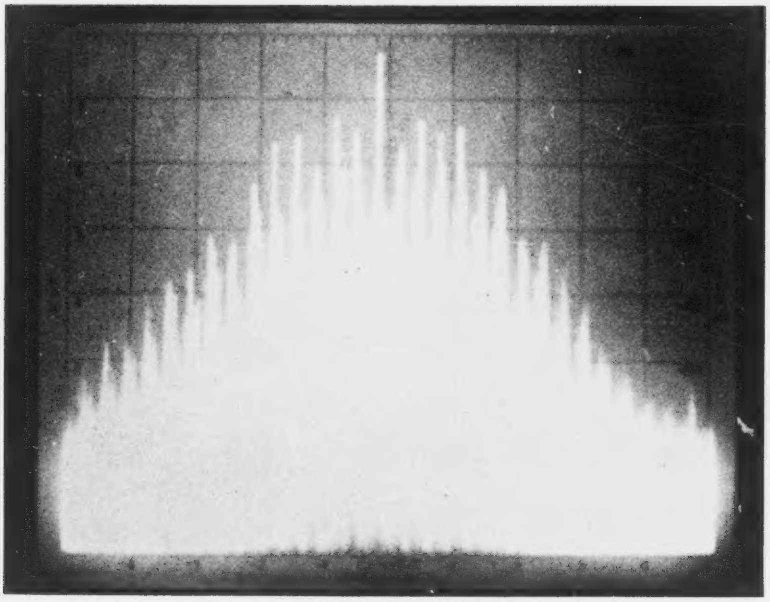

FIG. 6 SPECTRAL CONTENT OF 6 CHANNEL MODULATED AIRLINK TRANSMITTER

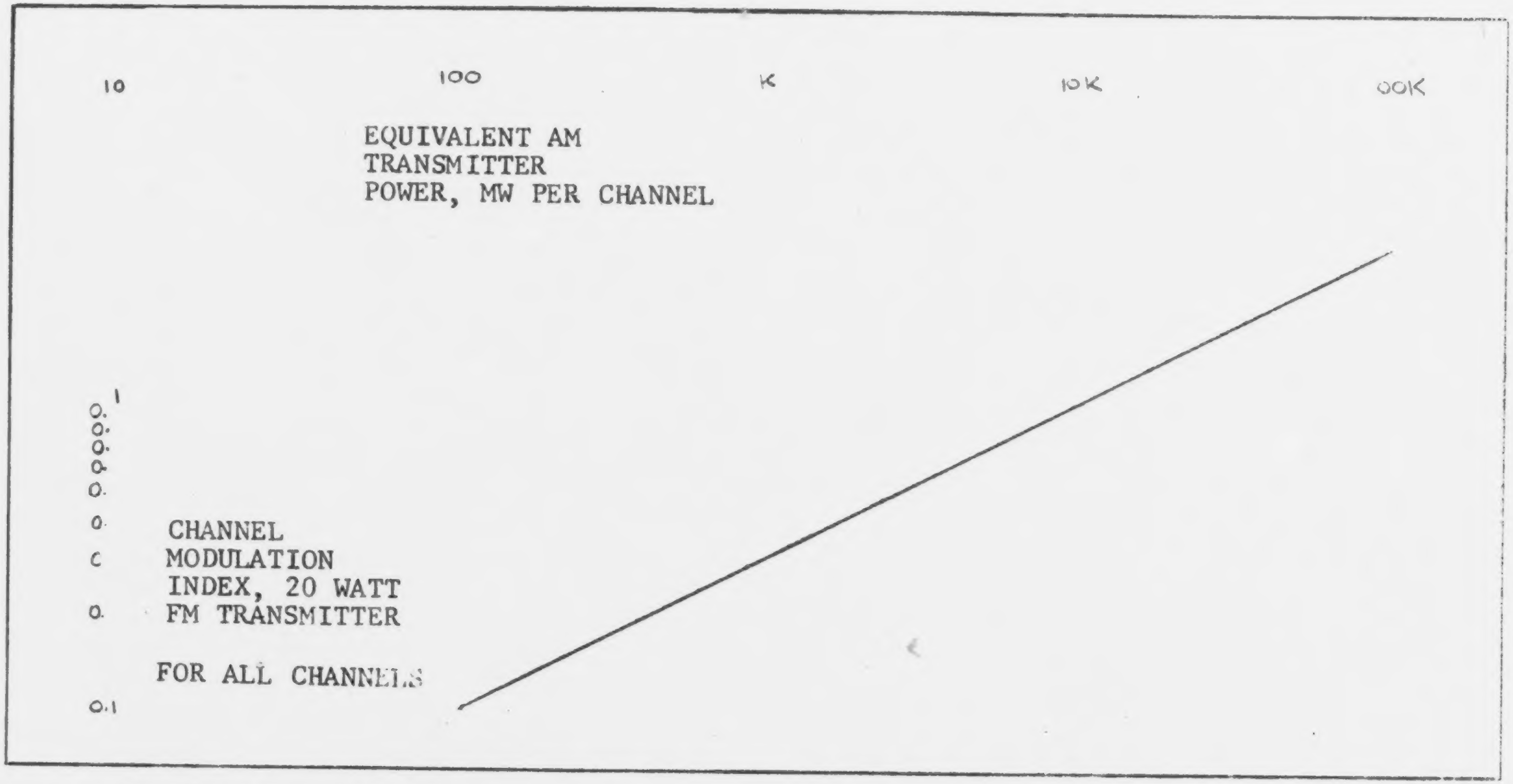

FIGURE 7. PLOT OF CHANNEL MODULATION INDEX M AGAINST THE EQUIVALENT AM TRANSMITTER POWER X TO PRODUCE THE SAME SIGNAL TO NOISE RATIO.

TABLE 1

NUMBER OF CHANNELS: 5

Channel Desig.	Freq. of Video Carr. MHz	Channel Mod. Index	FM Carrier Level for this Channel alone is at its Mod. Index	Power in Carrier	Equivalent Power in Sidebands
T 7	7.	1.00	.765	.585	.415
T 8	13.	1.00	.765	.585	.415
T 9	19.	0.97	.878	.770	.230
T 10	25.	0.96	.883	.780	.220
T 11	31.	0.96	.883	.780	.220
					1.500

This corresponds to 150% of energy in sidebands. In single channel FM, 100% of the energy is in the sidebands at a modulation index equal to 2.403. The equivalent of 150% of power in sidebands occurs at a modulation index of $2.403 \times \sqrt{1.5} = 2.403 \times 1.225 = 2.93$.

TABLE 2

NUMBER OF CHANNELS: 6

Channel Desig.	Freq. of Video Carr. MHz	Channel Mod. Index	FM Carrier Level for this Channel alone is at its Mod. Index	Power in Carrier	Equivalent Power in Sidebands
T 7	7	0.86	.824	.680	.320
T 8	13	0.77	.857	.735	.265
T 9	19	0.66	.894	.800	.200
T 10	25	0.62	.906	.822	.178
T 11	31	0.62	.906	.822	.178
T 12	37	0.60	.912	.832	.168
					1.309

This corresponds to 131% of energy in sidebands. In a single channel FM, 100% of the energy is in the sidebands at a modulation index of 2.403. The equivalent of 131% of power in sidebands occurs at a modulation index of $2.403 \times \sqrt{1.309} = 2.4 \times 1.14 = 2.73$

TABLE 3

NUMBER OF CHANNELS: 7

Channel Desig.	Freq. of Video Carr. MHz	Channel Mod. Index	FM Carrier Level for this Channel alone is at its Mod. Index	Power in Carrier	Equivalent Power in Sidebands
T 7	7	0.72	.874	.746	.254
T 8	13	0.50	.939	.873	.127
T 9	19	0.45	.950	.903	.097
T 10	26	0.40	.960	.922	.078
T 11	31	0.37	.966	.933	.067
T 12	37	0.36	.968	.937	.063
T 13	43	0.35	.970	.941	.059
					.645

64.5% of energy is in the sidebands. This is equivalent to an overall carrier level of $\sqrt{1.645} = \sqrt{.355} = .595$ at a modulation index equal to 1.34.

TABLE 4

NUMBER OF CHANNELS: 8

Channel Desig.	Freq. of Video Carr. MHz	Channel Mod. Index	FM Carrier Level for this Channel alone is at its Mod. Index	Power in Carrier	Equivalent Power in Sidebands
T 7	7	0.67	.891	.794	.216
T 8	13	0.40	.960	.922	.078
T 9	19	0.30	.978	.956	.044
T 10	25	0.25	.984	.968	.032
T 11	31	0.23	.987	.974	.026
T 12	37	0.21	.989	.978	.022
T 13	43	0.20	.990	.980	.020
S 1	49	0.19	.991	.982	.018
					.456

45.6% of the energy is in the sidebands. This is equivalent to an overall carrier level of:
$\sqrt{1.456} = \sqrt{.544} = .737$ at a modulation index of 1.06.

TABLE 5

NUMBER OF CHANNELS: 12*

Channel Desig.	Freq. of Video Carr. MHz	Channel Mod. Index	FM Carrier Level for this Channel alone is at its Mod. Index	Power in Carrier	Equivalent Power in Sidebands
T 7	7	1.70	.398	.159	.841
T 8	13	0.92	.799	.639	.361
T 9	19	0.63	.903	.815	.185
T 10	25	0.48	.943	.889	.111
T 11	31	0.38	.962	.926	.074
T 12	37	0.32	.975	.950	.050
T 13	43	0.28	.981	.962	.038
2	55	0.26	.983	.966	.034
3	61	0.26	.983	.966	.034
4	67	0.26	.983	.966	.034
5	77	0.26	.983	.966	.034
6	83	0.26	.983	.966	.034
					1.830

This corresponds to 183% of energy in sidebands. In a single channel FM, 100% of the energy is in the sidebands at a modulation index of 2.403. The equivalent of 183% of power in sidebands occurs at a modulation index of $2.403 \sqrt{1.83} = 2.403 \times 1.352 = 3.26$.

* 9,10 and 11 channels are derived by deletion of channels of the 12-channel baseband while remaining channels operated at the tabulated values.

TABLE 6

NUMBER OF CHANNELS: 13

Channel Desig.	Freq. of Video Carr. MHz	Channel Mod. Index	FM Carrier Level for this Channel alone is at its Mod. Index	Power in Carrier	Equivalent Power in Sidebands
T 7	7	2.02	.212	.045	.955
T 8	13	1.08	.729	.530	.470
T 9	19	0.74	.868	.753	.247
T 10	25	0.57	.920	.847	.153
T 11	31	0.45	.950	.903	.097
T 12	37	0.38	.964	.929	.071
T 13	43	0.33	.973	.947	.053
S 1	49	0.30	.978	.956	.046
2	55	0.30	.978	.956	.046
3	61	0.30	.978	.956	.046
4	67	0.30	.978	.956	.046
A	73	0.30	.978	.956	.046
S 5	79	0.30	.978	.956	.046
					2.322

This corresponds to 232% of energy in sidebands. In a single channel FM, 100% of the energy is in the sidebands at a modulation index of 2.403. The equivalent of 232% of power in sidebands occurs at a modulation index of 2.430 x $\sqrt{2.322}$ = 2.403 x 1.523 = 3.59.

TABLE 7

NUMBER OF CHANNELS: 14

Channel Desig.	Freq. of Video Carr. MHz	Channel Mod. Index	FM Carrier Level for this Channel alone is at its Mod. Index	Power in Carrier	Equivalent Power in Sidebands
T 7	7	1.54	.589	.346	.654
T 8	13	0.83	.835	.697	.303
T 9	19	0.57	.920	.847	.153
T 10	25	0.43	.954	.911	.089
T 11	31	0.35	.970	.941	.059
T 12	37	0.29	.979	.958	.042
T 13	43	0.25	.984	.968	.032
S 1	49	0.23	.987	.974	.026
2	55	0.23	.987	.974	.026
3	61	0.23	.987	.974	.026
4	67	0.23	.987	.974	.026
A	73	0.23	.987	.974	.026
S 5	79	0.23	.987	.974	.026
S 6	85	0.23	.987	.974	.026
					1.514

This corresponds to 151% of energy in sidebands. In a single channel FM, 100% of the energy is in the sidebands at a modulation index of 2.403. The equivalent of 151% of power in the sidebands occurs at a modulation index of $\sqrt{2.403}$ 1.51 = 2.403 x 1.23 = 2.96.

TABLE 8

NUMBER OF CHANNELS: 15

Channel Desig.	Freq. of Video Carr. MHz	Channel Mod. Index	FM Carrier Level for this Channel alone is at its Mod. Index	Power in Carrier	Equivalent Power in Sidebands
T 7	7	1.22	.661	.437	.563
T 8	13	0.66	.894	.800	.200
T 9	19	0.45	.950	.902	.098
T 10	25	0.34	.971	.943	.057
T 11	31	0.28	.981	.962	.038
T 12	37	0.23	.987	.974	.026
T 13	43	0.20	.990	.980	.020
S 1	49	0.18	.992	.984	.016
2	55	0.18	.992	.984	.016
3	61	0.18	.992	.984	.016
4	67	0.18	.992	.984	.016
A	73	0.18	.992	.984	.016
S 5	79	0.18	.992	.984	.016
S 6	85	0.18	.992	.984	.016
B	91	0.18	.992	.984	.016
					1.130

This corresponds to 113% of energy in sidebands. In a single channel FM, 100% of the energy is in the sidebands at a modulation index of 2.403. The equivalent of 113% of power in the sidebands occurs at a modulation index of $2.403 \sqrt{1.13} = 2.403 \times 1.063 = 2.57$.

TABLE 9

NUMBER OF CHANNELS: 16

Channel Desig.	Freq. of Video Carr. MHz	Channel Mod. Index	FM Carrier Level for this Channel alone is at its Mod. Index	Power in Carrier	Equivalent Power in Sidebands
T 7	7	0.97	.778	.606	.394
T 8	13	0.52	.934	.872	.128
T 9	19	0.27	.982	.964	.036
T 10	25	0.22	.988	.976	.024
T 11	31	0.18	.992	.984	.016
T 12	37	0.16	.993	.986	.014
T 13	43	0.15	.994	.988	.012
S 1	49	0.15	.994	.988	.012
2	55	0.15	.994	.988	.012
3	61	0.15	.994	.988	.012
4	67	0.15	.994	.988	.012
A	73	0.15	.994	.988	.012
S 5	79	0.15	.994	.988	.012
S 6	85	0.15	.994	.988	.012
B	91	0.15	.994	.988	.012
C	97	0.15	.994	.988	.012
					.732

73.2% of energy is in the sidebands. This is equivalent to an overall carrier level of $\sqrt{1.732} = \sqrt{.268} = .516$, which corresponds to a modulation index of 1.49.

TABLE 10

NUMBER OF CHANNELS: 17

Channel Desig.	Freq. of Video Carr. MHz	Channel Mod. Index	FM Carrier Level for this Channel alone is at its Mod. Index	Power in Carrier	Equivalent Power in Sidebands
T 7	7	0.76	.861	.741	.259
T 8	13	0.41	.958	.918	.092
T 9	19	0.28	.981	.962	.038
T 10	25	0.21	.989	.978	.022
T 11	31	0.17	.993	.986	.014
T 12	37	0.14	.995	.990	.010
T 13	43	0.12	.996	.992	.008
S 1	49	0.11	.997	.994	.006
2	55	0.11	.997	.994	.006
3	61	0.11	.997	.994	.006
4	67	0.11	.997	.994	.006
A	73	0.11	.997	.994	.006
S 5	79	0.11	.997	.994	.006
S 6	85	0.11	.997	.994	.006
B	91	0.11	.997	.994	.006
C	97	0.11	.997	.994	.006
D	103	0.11	.997	.994	.006
					.503

50.3% of energy is in the sidebands. This is equivalent to an overall carrier level of 1.503 = .497 = .705, which corresponds to a modulation index of 1.13.

Figure 25. 32 Amplifier Cascade

TABLE 11

NUMBER OF CHANNELS: 18

Channel Desig.	Freq. of Video Carr. MHz	Channel Mod. Index	FM Carrier Level for this Channel alone is at its Mod. Index	Power in Carrier	Equivalent Power in Sidebands
T 7	7	0.66	.894	.800	.200
T 8	13	0.36	.968	.937	.063
T 9	19	0.25	.984	.968	.032
T 10	25	0.19	.991	.982	.018
T 11	31	0.15	.994	.988	.012
T 12	37	0.13	.996	.992	.008
T 13	43	0.11	.997	.994	.006
S 1	49	0.10	.998	.996	.004
2	55	0.10	.998	.996	.004
3	61	0.10	.998	.996	.004
4	67	0.10	.998	.996	.004
A	73	0.10	.998	.996	.004
S 5	79	0.10	.998	.996	.004
S 6	85	0.10	.998	.996	.004
B	91	0.10	.998	.996	.004
C	97	0.10	.998	.996	.004
D	103	0.10	.998	.996	.004
E	109	0.10	.998	.996	.004
					.383

38.3% of energy is in the sidebands. This is equivalent to an overall carrier level of $\sqrt{1-.383} = \sqrt{.617} = .785$, which corresponds to a modulation index of 0.95.

TABLE 12

TABULATION OF POWER IN SIDEBAND COMPUTATION

Number of Channels	Equivalent % Power in Sidebands (based on 100% of sideband power at a Mod. index of 2.403).	Corresponding Index of Modulation for Multi-Channel System.
5	150%	2.93
6	131%	2.73
7	65%	1.34
8	46%	1.06
12 *	183%	3.26
13	232%	3.59
14	151%	2.96
15	113%	2.57
16	73%	1.49
17	50%	1.13
18	38%	0.95

* (9, 10, 11)

Sheet 1 of 2

TABLE 13

EQUIVALENT POWER IN MILLIWATTS REQUIRED TO PRODUCE EQUAL SIGNAL TO NOISE RATIO AS 20 WATT AIRLINK FDM/FM SYSTEM

Number of Channels:	5	6	7	8	12	13
Channel Desig.						
T 7	12,600	9,500	6,600	5,800	40,000	51,000
T 8	12,600	7,600	3,400	2,000	11,000	15,000
T 9	12,000	5,500	2,600	1,200	5,000	7,000
T 10	11,600	4,800	2,000	800	3,000	3,600
T 11	11,600	4,800	1,750	660	1,800	2,600
T 12	N/A	4,600	1,600	550	1,300	1,800
T 13	-	-	1,550	500	1,000	1,400
S 1	-	-	-	450	-	1,100
2	-	-	-	-	850	1,100
3	-	-	-	-	850	1,100
4	-	-	-	-	850	1,100
A	-	-	-	-	-	1,100
5 or S5	-	-	-	-	850	1,100
6 or S6	-	-	-	-	850	-
B	-	-	-	-	-	-
C	-	-	-	-	-	-
D	-	-	-	-	-	-
E	-	-	-	-	-	-
TOTAL	60,400	36,800	19,500	11,960	67,350	89,000

TOTAL REQUIRED EQUIVALENT AM POWER FOR EQUAL S/N.

Sheet 2 of 2 TABLE 13

EQUIVALENT POWER IN MILLIWATTS REQUIRED TO PRODUCE EQUAL SIGNAL TO NOISE RATIO AS 20 WATT AIRLINK FDM/FM SYSTEM

Number of Channels:	14	15	16	17	18
Channel Desig.					
T 7	31,000	20,000	12,000	7,600	5,500
T 8	9,000	5,500	3,500	2,200	1,600
T 9	4,200	2,600	900	1,000	800
T 10	2,300	1,500	600	550	450
T 11	1,500	1,000	400	360	280
T 12	1,100	660	320	250	210
T 13	800	500	280	180	150
S 1	660	400	280	150	126
2	660	400	280	150	126
3	660	400	280	150	126
4	660	400	280	150	126
A	660	400	280	150	126
5 or S5	660	400	280	150	126
6 or S6	660	400	280	150	126
B	-	400	280	150	126
C	-	-	280	150	126
D	-	-	-	150	126
E	-	-	-	-	126
TOTAL	53,720	34,960	20,520	13,640	10,376

TOTAL REQUIRED EQUIVALENT AM POWER
FOR EQUAL S/N.

"PERFORMANCE OF MULTI-CHANNEL MICROWAVE LOCAL DISTRIBUTION SYSTEMS"

A. H. Sonnenschein
Assistant to the President
Theta-Com of California
9320 Lincoln Boulevard
Los Angeles, California 90045

It has now been about seven years since the development of multi-channel microwave local distribution systems for the CATV industry first started in 1965, although it seems like yesterday to those of us who have been so heavily involved in this exciting and dynamic field. More progress has been made during the past year, since the 1971 NCTA convention, than in all prior years, insofar as putting multi-channel local distribution systems in actual operational day to day use. It can now be said that AML microwave is no longer a developmental technique, but a technique which is essential to progressive cable operators who wish to achieve optimum financial performance for themselves and optimum signal quality for their subscribers.

Before getting into a detailed discussion of AML's performance capabilities, I think that it would be desirable to briefly review the equipment's salient design features. A simplified block diagram of the AML system is shown in Figure 1.

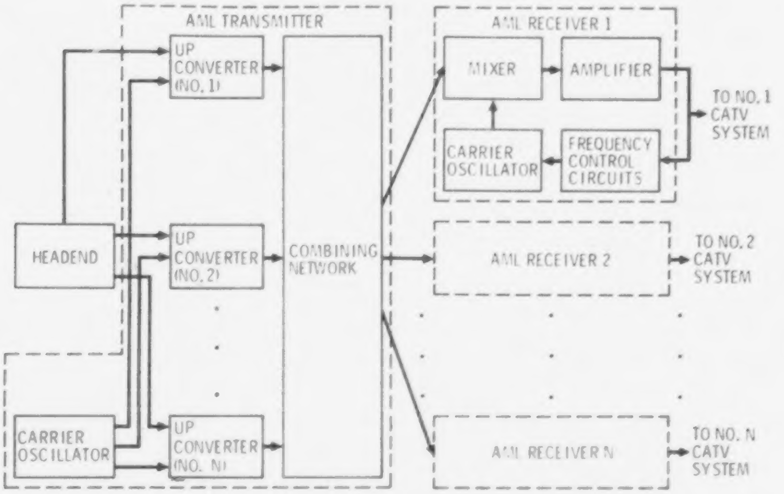
AML TRANSMITTER
UP CONVERTER (NO. 1)
UP CONVERTER (NO. 2)
UP CONVERTER (NO. N)
COMBINING NETWORK
HEADEND
CARRIER OSCILLATOR
AML RECEIVER 1
MIXER
AMPLIFIER
CARRIER OSCILLATOR
FREQUENCY CONTROL CIRCUITS
TO NO. 1 CATV SYSTEM
AML RECEIVER 2
TO NO. 2 CATV SYSTEM
AML RECEIVER N
TO NO. N CATV SYSTEM

Figure 1. AML System - Simplified Block Diagram

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Signals are fed to the AML transmitter from a conventional headend, where they should be processed by conventional heterodyne processing equipment. The AML does not require the use of video carriers with phaselocked frequency spacings in order to minimize intermodulation products. This avoids the necessity for going down to video baseband by demodulating and remodulating with phaselocked modulators. It further eliminates the necessity for non-standard channel assignments, which would require special channel converters in all subscribers' homes and which would severely aggravate venetian blind phenomena resulting from co-channel interference from off-the-air radiation into your subscribers' sets.

The processed VHF signals from the headend are then translated in frequency into the microwave range; i.e., into the 12 GHz CARS band. This is done by a parametric upconverter, wherein the VHF signals are mixed with a carrier oscillator. The upconverter selects the sum of the VHF and carrier frequency and rejects the carrier itself as well as the lower sideband which is the difference between these two frequencies. One way of looking at the action of the upconverter is therefore to consider it as a single sideband suppressed carrier AM system. Another way of looking at it, is that the VHF signal is maintained with its modulation intact and merely translated in frequency into the microwave range. The modulation of the microwave signal therefore remains in the form of vestigial sideband AM. This is the designation which the FCC has assigned to our type of modulation.

You will note that all channels are processed separately in all the active stages of the AML transmitter. This is the design feature which virtually eliminates the possibility of crossmodulation and intermodulation from arising in the transmitter and is what enables the AML system to achieve unmatched performance in this regard.

The microwave output from every upconverter is then combined in a passive network to be fed to the transmitting antennas. One of these antennas is used to radiate the signal to each of the desired receiving sites. At each receiver, the incoming microwave signal is mixed with another carrier oscillator, which in this case serves the function of the receiver's local oscillator, to bring the signal down to VHF again. The carrier oscillator in the receiver is phaselocked to the carrier oscillator in the transmitter so that the final receiver output frequencies are in effect phaselocked to the transmitter input frequencies. This avoids the venetian blind effect from local off-the-air radiation, which would occur whenever channels must be shifted in frequency without means for phaselocking them to the local off-the-air stations.

You will note that the frequency translation in the receiver is handled in one block. The reason why this is feasible, is that the signal levels in the receivers are, of course, much lower than those in the transmitter, so that the types of non-linearities which give rise to intermodulation and crossmodulation are not a limiting factor here.

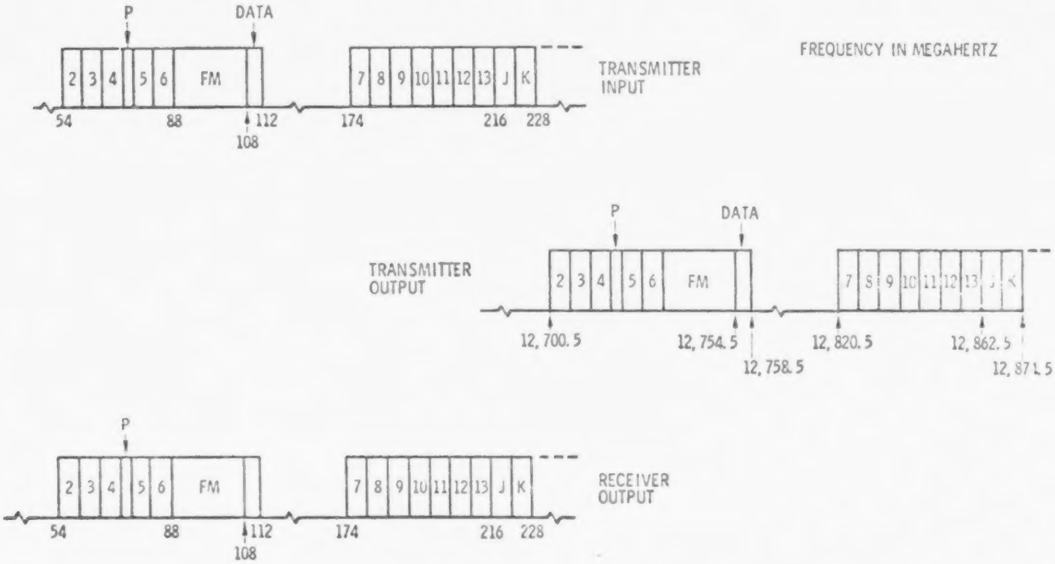
FREQUENCY IN MEGAHERTZ
P
DATA
2
3
4
5
6
FM
7
8
9
10
11
12
13
J
K
TRANSMITTER INPUT
54
88
108
112
174
216
228
TRANSMITTER OUTPUT
12,700.5
12,754.5
12,758.5
12,820.5
12,862.5
12,874.5
RECEIVER OUTPUT

Figure 2. AML Frequency Chart

The frequency relationships involved in the AML system operation are shown in Figure 2. The upper portion of this illustration shows VHF channel assignments. I have only shown the 12 standard VHF channels plus the FM broadcast band. Needless to say, subject only to FCC approval, the AML can handle mid-band and super-high channels, and actually even sub-low channels, with equal facility. The entire FM broadcast band is transmitted as one channel. In some cable systems, four special video channels are transmitted in lieu of the FM broadcast band. The frequency range from 108 to 112 is used to carry the downstream digital data for Theta-Com's Subscriber Response System or for similar interactive systems.

The AML transmitter output frequencies, which are shown in the middle portion of the illustration, are simply derived by adding the transmitter pump, or carrier oscillator, frequency to the VHF input frequencies. Conversely, the receiver output frequencies are derived by subtracting the same carrier frequency from the transmitted frequency. Evidently, if the carrier oscillator in the receiver is phaselocked to the carrier oscillator in the transmitter, the final receiver output frequencies are precisely equal to the transmitter input frequencies. A pilot tone is transmitted in the AML system in the frequency range between channels 4 and 5 for the purpose of phaselocking the local oscillator in the receiver to the pump frequency in the transmitter. The pilot tone is also used for automatic gain control in the receiver in order to reduce the effect of atmospheric fading phenomena.

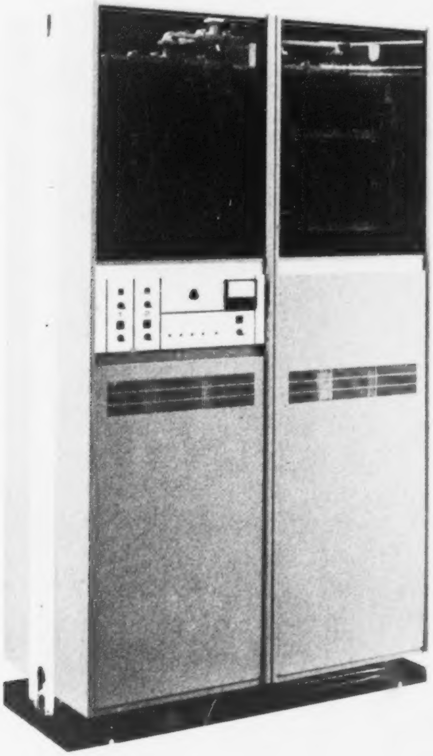

Figure 3. AML Transmitter

Figure 3 shows an AML transmitter. This particular two-rack configuration can handle up to 15 channels as well as the pilot tone. Or this might be 14 video channels, the FM band, and the pilot tone. Each rack accommodates up to 8 channels and the system employs modular techniques so that only as many racks or channels within racks need to be procured as may be required for the particular application. Additional channel modules or additional racks can be added from time to time as the number of channels carried by the cable operator increases.

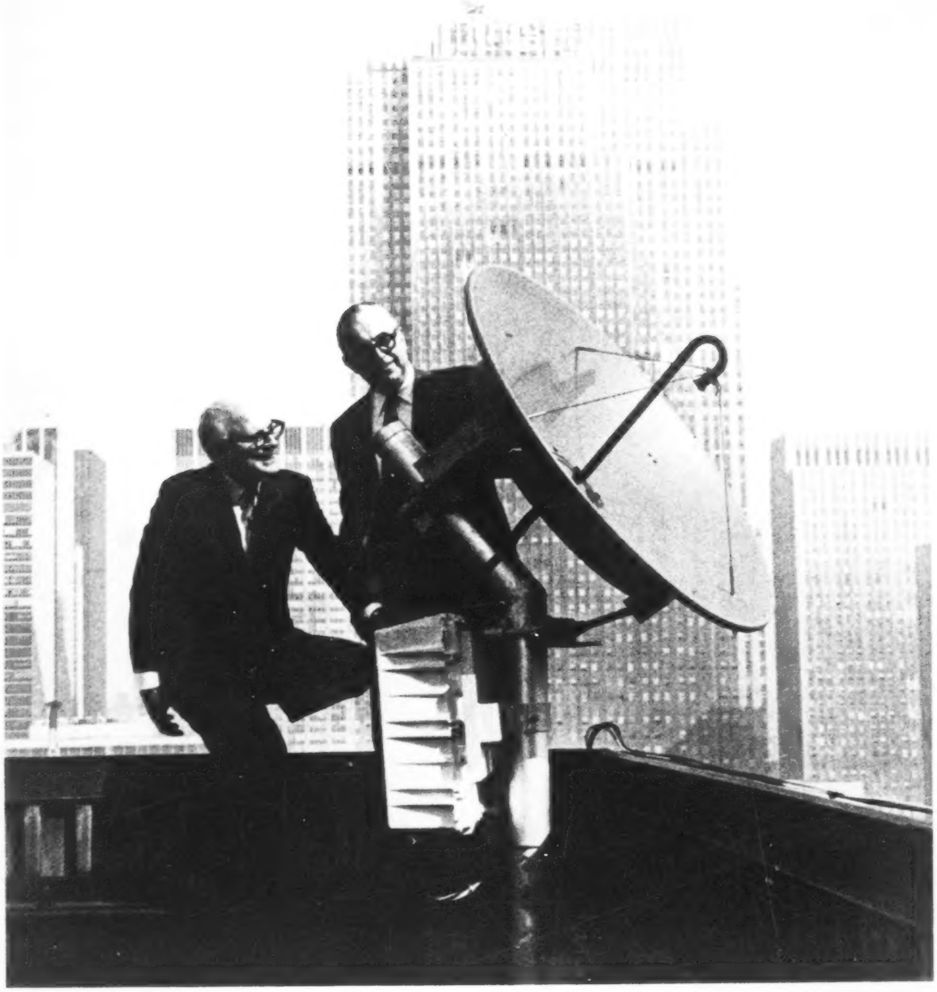

Figure 4. AML Receiver Installation

An actual receiver installation is shown in Figure 4. The receiver is cable powered, in a fashion similar to that of a conventional trunkline amplifier, and is capable of operating outdoors over a temperature range from -40°F to +120°F.

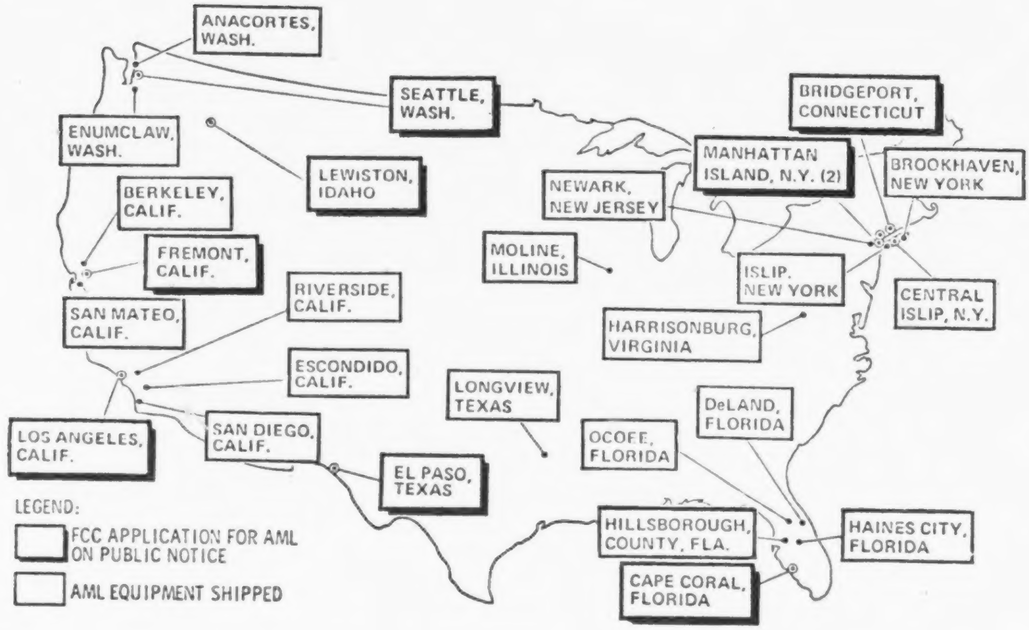
ANACORTES, WASH.
SEATTLE, WASH.
ENUMCLAW, WASH.
BERKELEY, CALIF.
FREMONT, CALIF.
SAN MATEO, CALIF.
LEWISTON, IDAHO
RIVERSIDE, CALIF.
ESCONDIDO, CALIF.
LOS ANGELES, CALIF.
SAN DIEGO, CALIF.
EL PASO, TEXAS
LONGVIEW, TEXAS
MOLINE, ILLINOIS
NEWARK, NEW JERSEY
MANHATTAN ISLAND, N.Y. (2)
BRIDGEPORT, CONNECTICUT
BROOKHAVEN, NEW YORK
ISLIP, NEW YORK
CENTRAL ISLIP, N.Y.
HARRISONBURG, VIRGINIA
DeLAND, FLORIDA
OCOEE, FLORIDA
HILLSBOROUGH, COUNTY, FLA.
HAINES CITY, FLORIDA
CAPE CORAL, FLORIDA
LEGEND:
FCC APPLICATION FOR AML ON PUBLIC NOTICE
AML EQUIPMENT SHIPPED

Figure 5. AML Installation Status as of April, 1972

Figure 5 shows the status of AML installations throughout the country as of April, 1972. The locations having a heavy border show actual equipment shipments. The other locations shown indicate those FCC applications for AML, which have gone on public notice. At the present time, Theta-Com's AML leads in the number of FCC filings and I would like to emphasize that all these filings are bona fide filings made and paid for by our customers. Insofar as actual shipments and installations are concerned, as of the time of the writing of this paper, Theta-Com's AML is still the only multi-channel local distribution system in actual subscriber service by cable system operators all over the country. The climatic conditions encountered range widely from the Pacific Northwest, Northern as well as Southern California, Texas, Florida and the New York and Long Island areas. The number of FCC filings, the granting of FCC construction permits, and the number of AML shipments and installations has been rising exponentially and it is really quite difficult to keep these statistics up-to-date.

But picture quality is really the name of the game. Let us now go to my primary topic, some hard numbers concerning actual performance. In each case, I plan to show you the block diagram of our test instrumentation, photographs of the instrumentation employed, as well as the data itself.

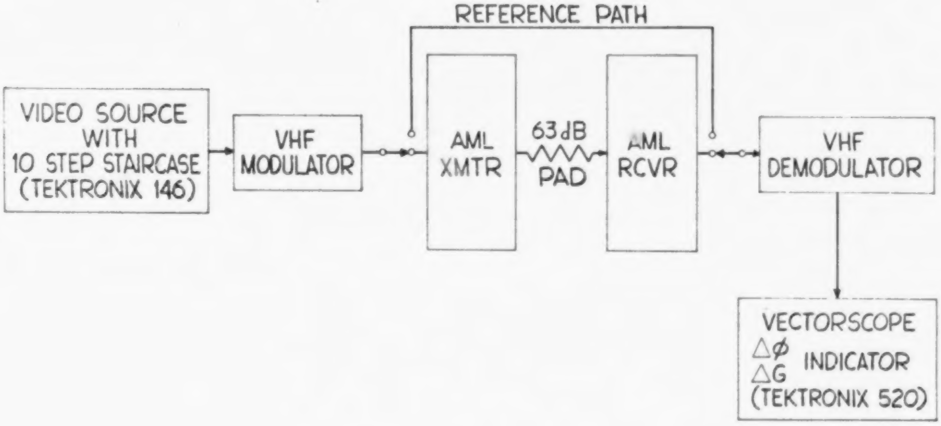
REFERENCE PATH
VIDEO SOURCE WITH 10 STEP STAIRCASE (TEKTRONIX 146)
VHF MODULATOR
AML XMTR
63dB PAD
AML RCVR
VHF DEMODULATOR
VECTORSCOPE $\Delta\phi$ ΔG INDICATOR (TEKTRONIX 520)

Figure 6. Block Diagram - Differential Phase and Gain Tests

Figure 6 shows a block diagram of the test setup employed to make differential phase and gain measurements. These measurements are accomplished at video baseband using a Model Tektronix 146 TV Signal Generator and a Tektronix Model 520 Vectorscope as a differential phase and a differential gain indicator. The necessity for making these measurements at video baseband is unfortunate, inasmuch as it requires the use of a VHF modulator and a VHF demodulator, the combination of which has much more differential phase and gain deterioration than does the AML system. It is therefore necessary prior to each measurement to calibrate the reference path without the AML and subsequently to measure the change of differential phase and gain when the AML system is inserted.

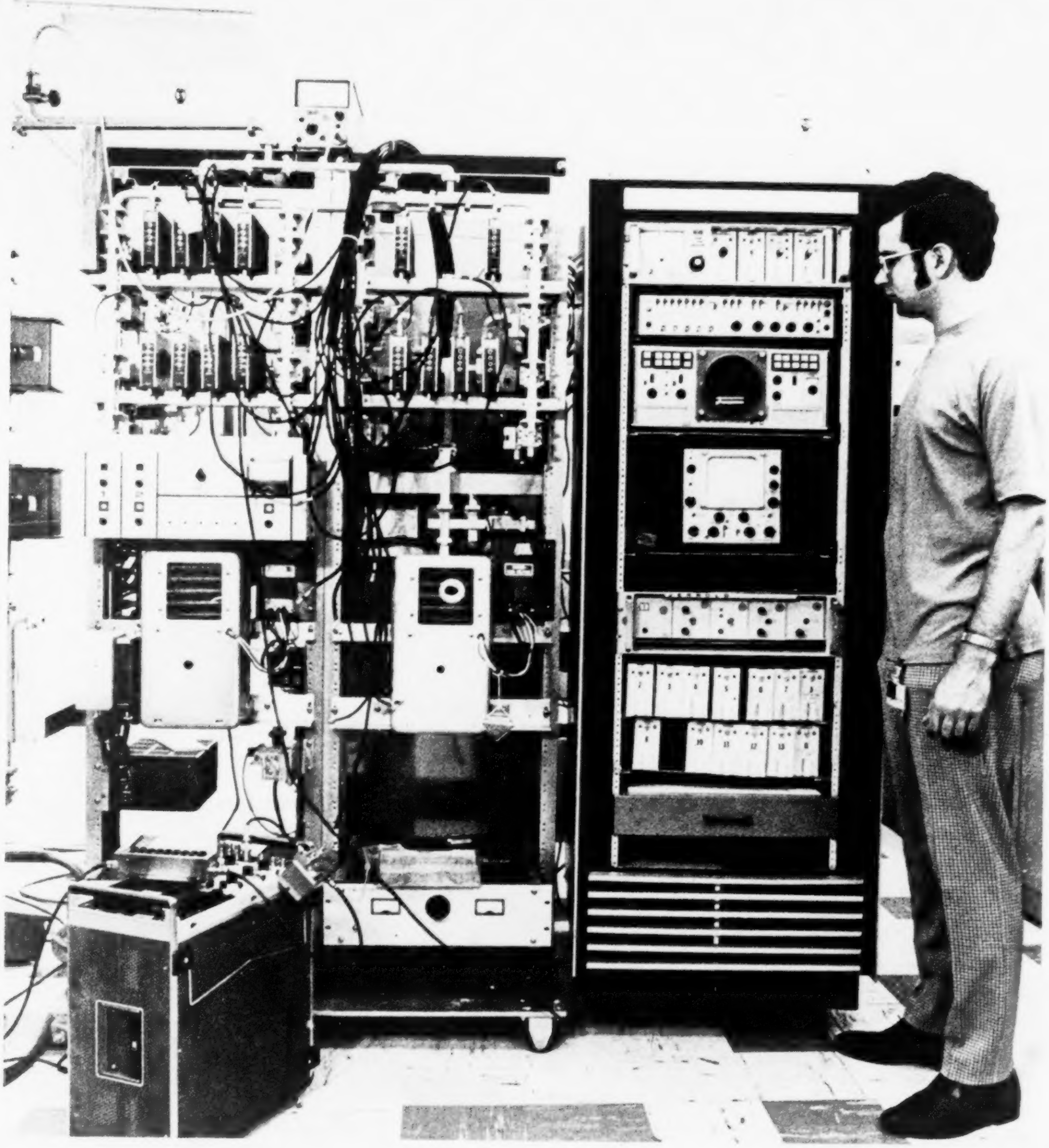

Figure 7. Differential Phase and Gain Instrumentation

The actual instrumentation employed for the differential phase and gain measurement is shown in Figure 7. The rack of equipment at the right-hand side of this photograph contains the test equipment. The unit at the top of the rack is the modulator, the unit just below it is the Tektronix test signal generator, and the third unit from the top is the Vectorscope. The equipment below the oscilloscope is the demodulator. Shown below that are various plug-in tuning units for the modulator and the demodulator in order to permit measurements on all channels.

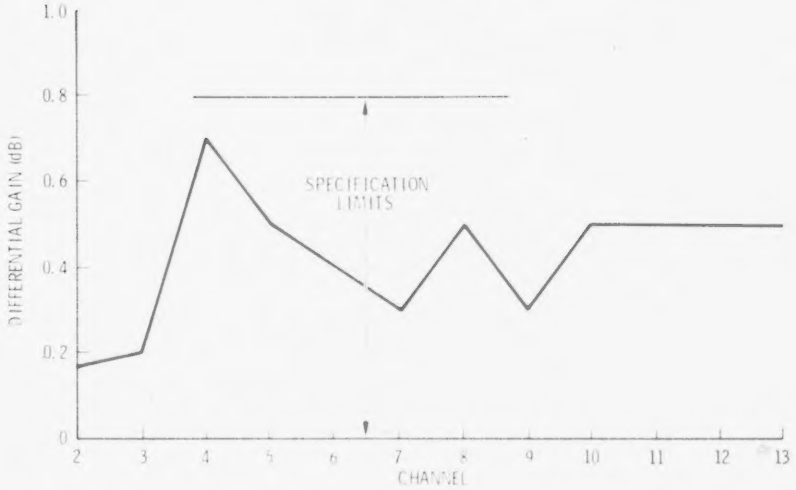

Figure 8. Differential Gain Response of AML System

The results of the differential gain response of a complete AML system, that is including the transmitter as well as the receiver, may be seen on Figure 8 to be well within the specification limits of plus or minus 0.4 dB on all channels.

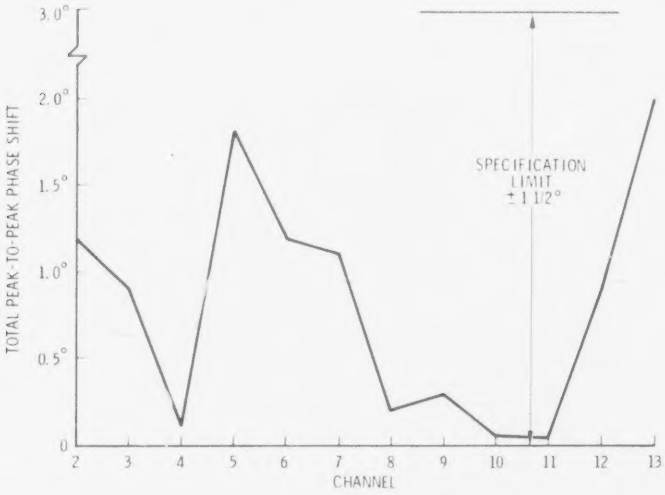

Figure 9. Differential Phase Response of AML System

The differential phase response of the AML system is shown on Figure 9. Excessive phase shift would result in changes in color, as a function of changes in color intensity. The response of the AML system may be seen to be well within specifications and far better than CATV system requirements.

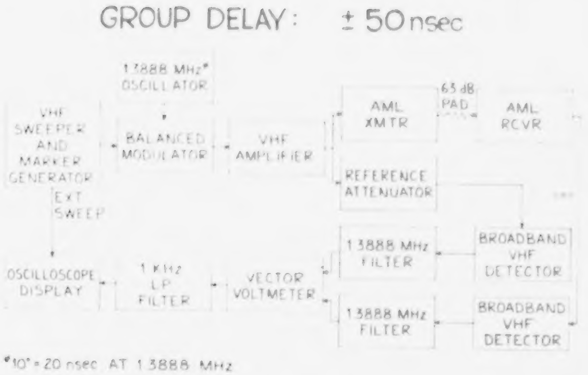
GROUP DELAY: ± 50 nsec
1.3888 MHz* OSCILLATOR
VHF SWEEPER AND MARKER GENERATOR
BALANCED MODULATOR
VHF AMPLIFIER
AML XMTR
63 dB PAD
AML RCVR
REFERENCE ATTENUATOR
EXT SWEEP
1.3888 MHz FILTER
BROADBAND VHF DETECTOR
OSCILLOSCOPE DISPLAY
1 KHz LP FILTER
VECTOR VOLTMETER
1.3888 MHz FILTER
BROADBAND VHF DETECTOR
*10° = 20 nsec AT 1.3888 MHz

Figure 10. Block Diagram - Group Delay Instrumentation

The block diagram of the test setup for group delay measurements is shown in Figure 10.* Essentially, this method of measurement employs a Vector voltmeter to measure the phase shift of the 1.3888 MHz modulation on a VHF carrier, as the latter is swept through all channels. The odd modulation frequency is chosen for convenience of calibration so that a 10 degree phase shift, as measured on the Vector voltmeter, is equivalent to a time delay of 20 nanoseconds. This makes it convenient to use the angular offset switch on the Vector voltmeter to calibrate the oscilloscope display to read directly in nanoseconds. The measurement technique shown on this block diagram has several advantages, the most significant of which is the fact that measurements are made directly at VHF rather than at video baseband, thus eliminating the necessity for using modulators and demodulators. This is particularly advantageous inasmuch as the modulators and demodulators have much more group delay themselves, than what we are trying to measure on AML.

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*I am indebted to William H. Lambert and Andrew W. Barnhart for suggesting this method of measurement to us.

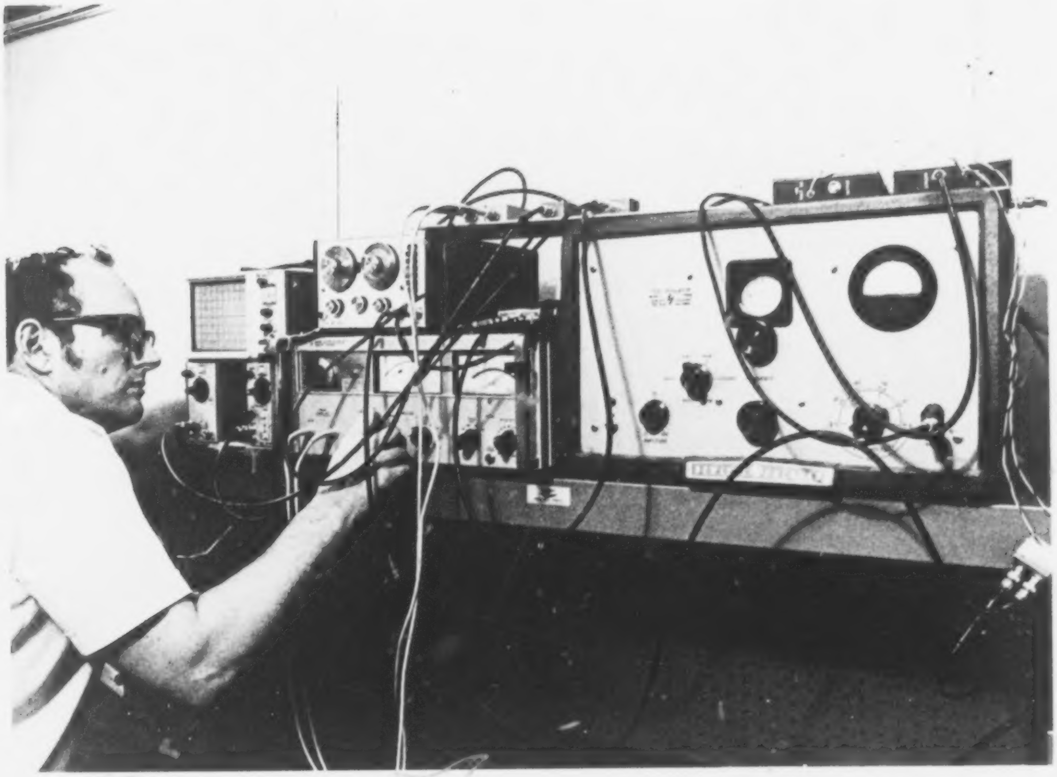


Figure 11. Group Delay Instrumentation

A photograph of the actual instrumentation employed is shown in Figure 11. The technician's hand is on the Vector voltmeter. Directly above the Vector voltmeter is the sweep generator which is used to sweep across the entire VHF band. The test oscillator on the right side of the bench is being used to furnish the 1.3888 MHz modulation signal, but we will replace this shortly with a small fixed frequency oscillator. The oscilloscope shown on the left side of the bench is a storage oscilloscope, which makes it more convenient to make accurate measurements while sweeping very slowly across the band for each channel.

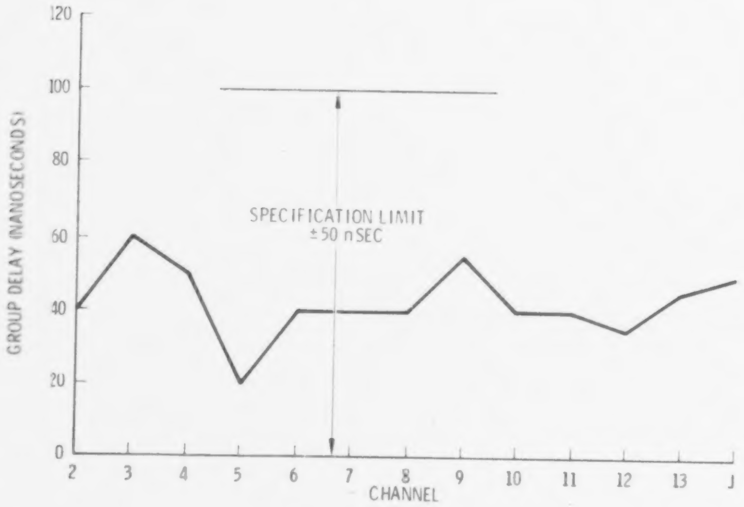


Figure 12. Group Delay Response of AML System

The group delay response of the AML system is shown on Figure 12. It may be seen to be well within specifications and again much below the threshold of discernibility.

For a fixed transmitter power output and a fixed path, the major remaining parameter affecting the AML system's propagation reliability, is the receiver noise figure.

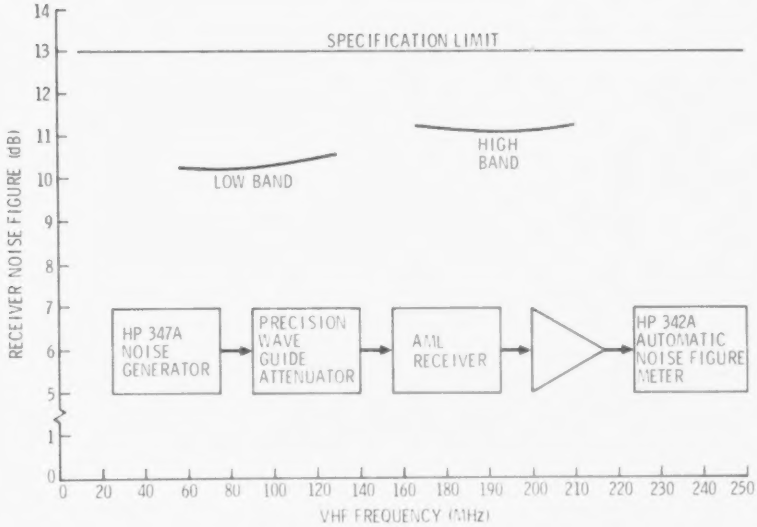


Figure 13. AML Receiver Noise Figure Measurements and Block Diagram

A graph of the noise figure of a typical AML receiver is shown on Figure 13, together with a block diagram of the test instrumentation. The discontinuity in the curve is due to the fact that the current receiver configuration processes the low and high band separately. We will have a new receiver design available shortly which can also handle the mid and super-high bands with performance comparable to that shown here. It may be noted that the noise figure measured is well within specifications. Measurements made on a single receiver are, however, not particularly conclusive.

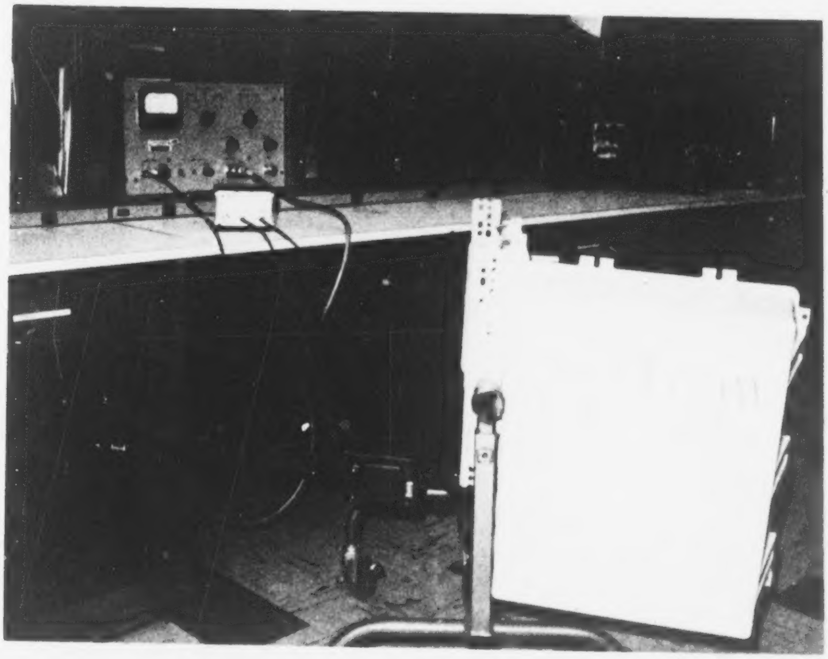


Figure 14. Noise Figure Measurement Instrumentation

Connected to the lower end of the AML receiver are a Hewlett Packard Model 347A noise generator and a precision waveguide attenuator. On the bench are a small VHF amplifier and a Hewlett Packard Model 342A Noise Figure Meter. The latter is operated at a signal level where changes of ±10 dB do not affect the measurement. The entire setup is periodically recalibrated at the Hughes Primary Standards Laboratory. We have found our test results to be significantly more conservative than the conventional Field Intensity Meter method.

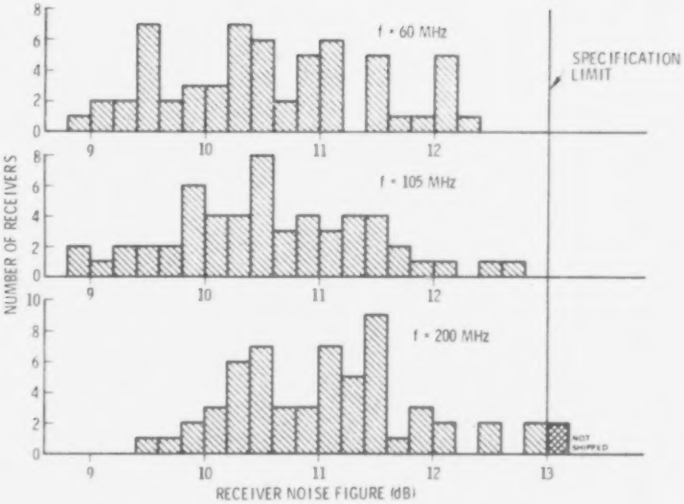
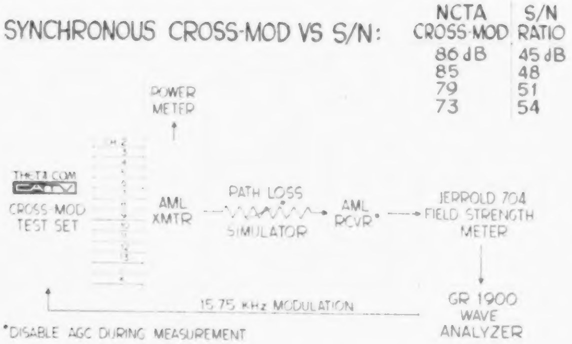


Figure 15. Statistical Distribution of Receiver Noise Figure

Figure 15 illustrates the statistical distribution of receiver noise figure measurements made on a very large number of different receivers. Measurements are shown here at both ends of the band as well as in the middle. Plotted on the horizontal scale is the receiver noise figure and plotted on the vertical scales are histograms of the number of receivers having the various noise figures. It may be noted that the measurements are scattered over a range of in excess of 3 dB, and that all measurements (except for two receivers that were obviously not shipped) are well within specification. There is, however, an unmistakable trend indicating that the average noise figure at the high end of the band is slightly inferior to that at lower frequencies, but nevertheless well within specifications.


SYNCHRONOUS CROSS-MOD VS S/N:
POWER METER
THETA COM
CATV
CROSS-MOD TEST SET
CH 2
AML XMTR
PATH LOSS SIMULATOR
AML RCVR*
JERROLD 704 FIELD STRENGTH METER
GR 1900 WAVE ANALYZER
15.75 KHz MODULATION

NCTA CROSS-MOD	S/N RATIO
86 dB	45 dB
85	48
79	51
73	54

*DISABLE AGC DURING MEASUREMENT

Figure 16. Block Diagram - Crossmodulation Measurements

A block diagram of the synchronous crossmodulation measurement setup is shown in Figure 16. The instrumentation employed is the Theta-Com (former Kaiser) CATV Division's Model KTSS crossmodulation test set with the Jerrold 704 field strength meter and a General Radio Model 1900 wave analyzer. Measurements are made synchronously in accordance with the NCTA method. I am sure that you are all familiar with this method and I need not dwell on it. The AML system's crossmodulation specifications are tabulated in the upper right-hand corner of this chart. Various different specification limits are given because it is possible to trade off signal-to-noise ratio versus crossmodulation performance. For instance, if the microwave path is long and the amplifier cascade is short, overall performance can be improved by driving the receiver harder to a higher signal-to-noise ratio. Conversely, on short microwave paths with relatively long cascades, overall performance and reliability are improved by choosing a lower signal-to-noise ratio and a higher crossmodulation performance.

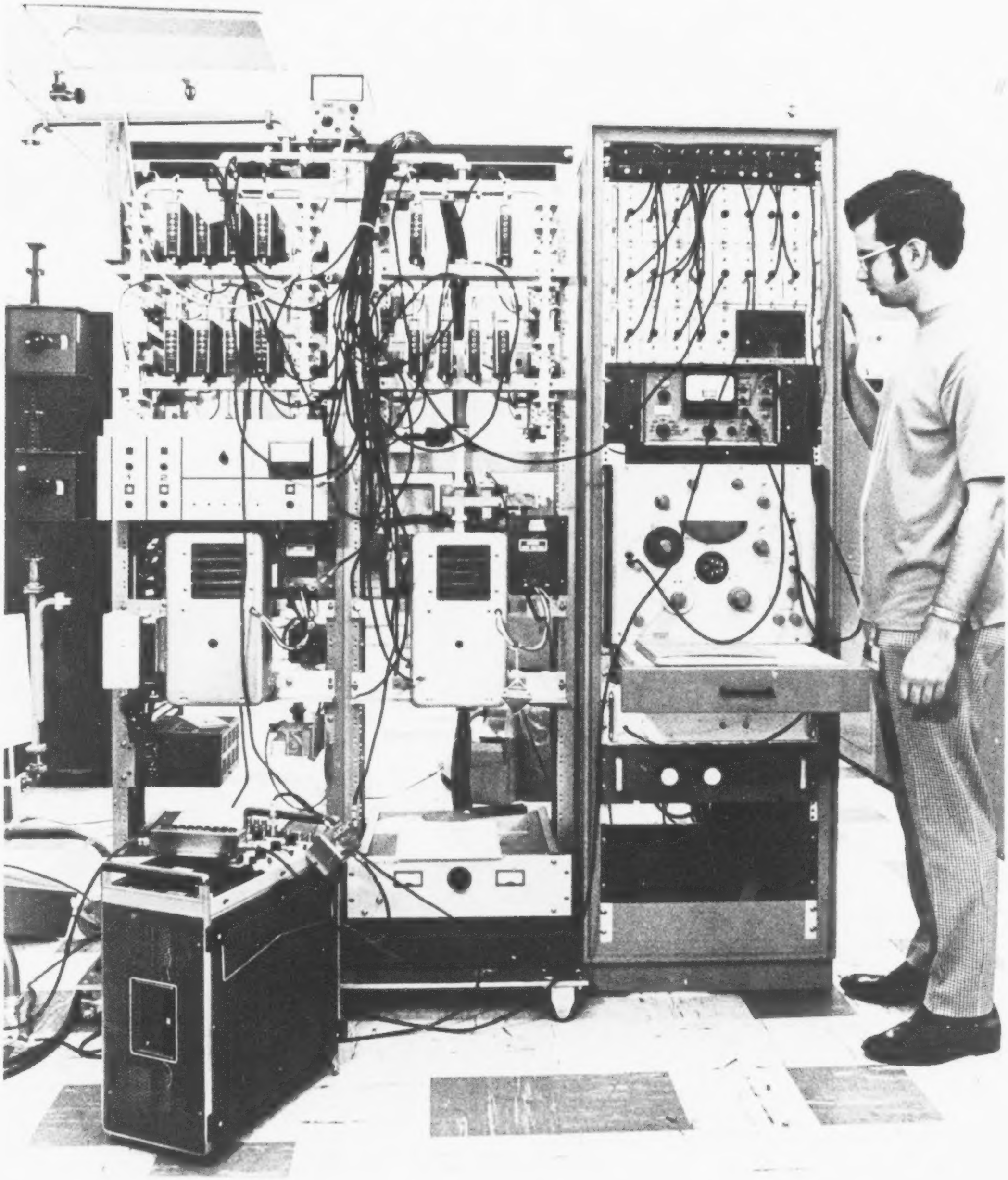


Figure 17. Synchronous Crossmodulation Instrumentation

A photograph of the actual crossmodulation instrumentation employed is shown in Figure 17. The test instrumentation is shown in the third rack at the right. The three rows of modules shown at the top are the various channels of the crossmodulation analyzer. Just below them is the field strength meter and the large instrument in the center of the rack is the General Radio wave analyzer. Incidentally, the test setup shown here is one of our final quality assurance test stations, and all AML equipment currently being shipped goes through this test station, not on a sampling basis, but on a one hundred percent test basis.

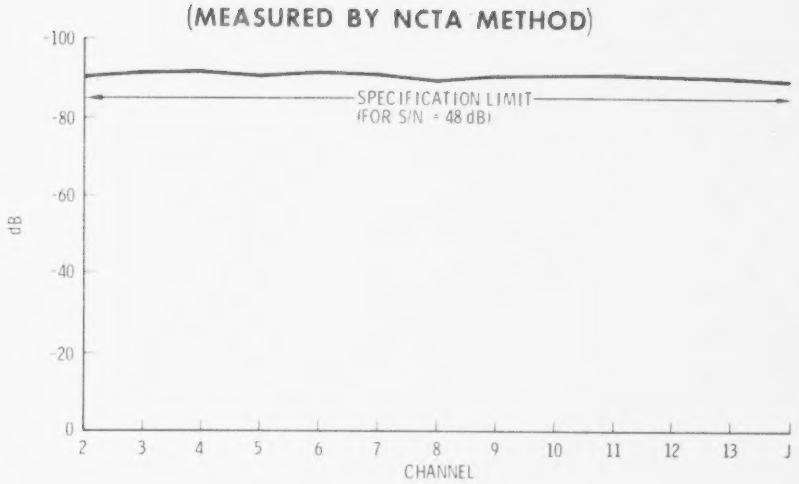


Figure 18. Crossmodulation Performance of AML System

The results of the crossmodulation measurements of a typical AML system are shown in Figure 18. Because of the high degree of crossmodulation suppression, the graph is somewhat difficult to read, expanded versions will be shown later. In the meantime, you can see that the crossmodulation hovers within several dB of 90 dB. This is well within the specification limits indicated. It should also be pointed out that because of the practical limits of the instrumentation employed, the instrumentation noise level is of the same order of magnitude of what we are trying to measure here. For that reason, and because of the masking effects of the instrumentation noise, I believe that the actual crossmodulation performance is even better than shown on the graph.

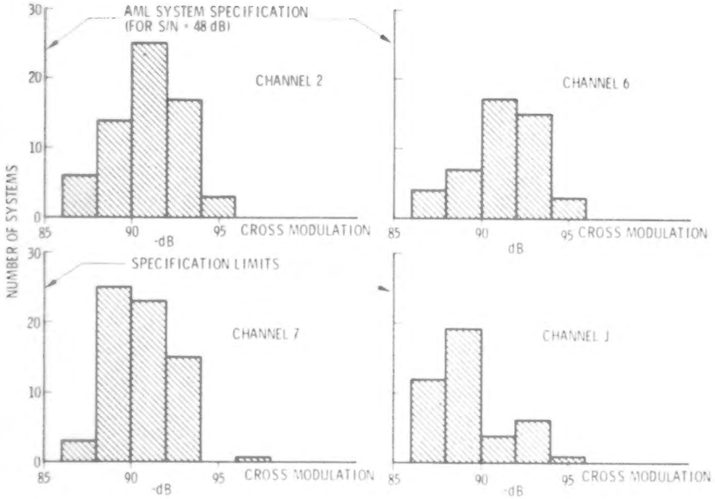


Figure 19. Statistical Distribution of AML System Synchronous Crossmodulation

Here again measurements on a single AML system are not necessarily conclusive. I am therefore showing on Figure 19 the statistical distribution of AML system crossmodulation in several typical channels at both ends as well as in the middle of the band. The horizontal axis shows the synchronous crossmodulation and the vertical axis shows the number of AML systems having any given crossmodulation performance. You will note that the average of the measurements is significantly better than the specification limit and that no measurement falls below the stated limits.

Just as measurements on just a few systems are not sufficient in order to insure proper performance of all systems, neither are measurements at normal room temperature particularly meaningful. The performance of all AML equipment is therefore carefully checked over the entire range of environmental test conditions specified.

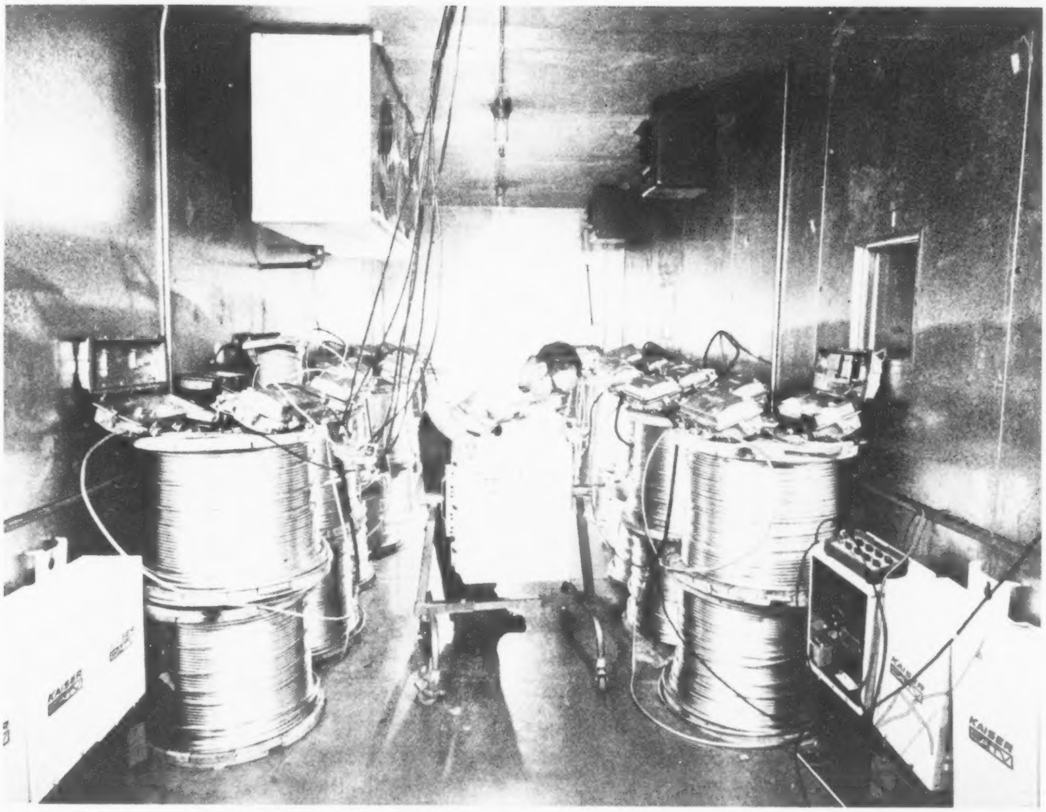


Figure 20. Environmental Test Chamber

Figure 20 shows an AML receiver being set up for testing in one of our environmental test chambers. The reels of cable and trunkline amplifiers in the test chamber have nothing to do with the measurements which I will report shortly, but may be of interest to you inasmuch as they are the 16 amplifier dual cable two-way CATV system which is currently being installed in El Segundo, California for the purpose of testing our new Subscriber Response System. To get back to the AML, we have tested a large number of AML receivers and transmitters in combination as well as separately, in this test chamber, over the various temperature ranges specified in each case.

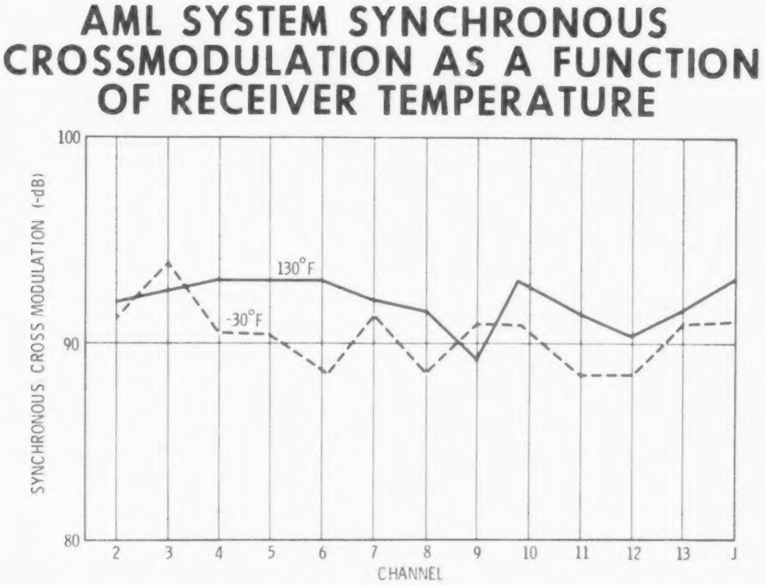
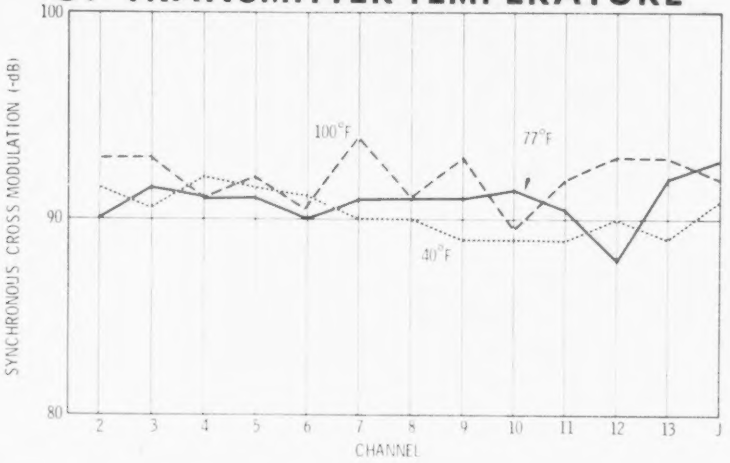


Figure 21

Figure 21 shows the effect on synchronous crossmodulation performance as the receiver temperature is varied from -30°F to +130°F. Performance remains well within specification.



AML SYSTEM SYNCHRONOUS CROSSMODULATION AS A FUNCTION OF TRANSMITTER TEMPERATURE

Figure 22

Figure 22 shows the effects on crossmodulation performance as the transmitter is varied in temperature from 77°F up to +100°F and down to 40°F. Here again performance remains well within the specification of 85 dB. You will have noticed that the temperature range for the receiver, which is intended for outdoor mounting under extreme environmental conditions, is much wider than that for the transmitter which will usually be mounted in the headend.

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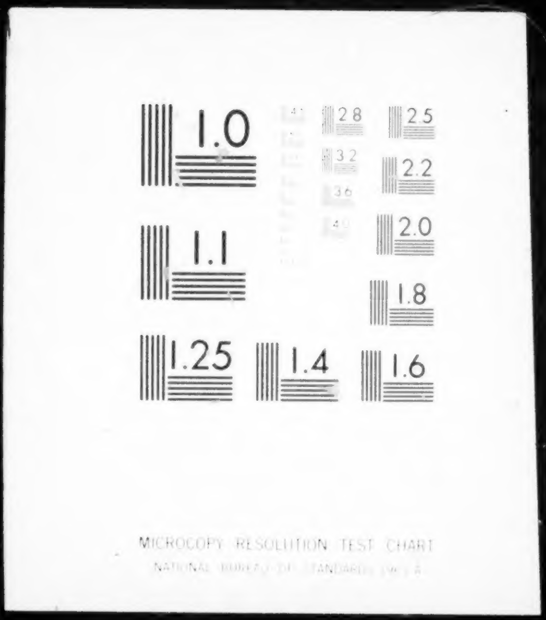
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AML SYSTEM SIGNAL TO NOISE RATIO AS A FUNCTION OF RECEIVER TEMPERATURE

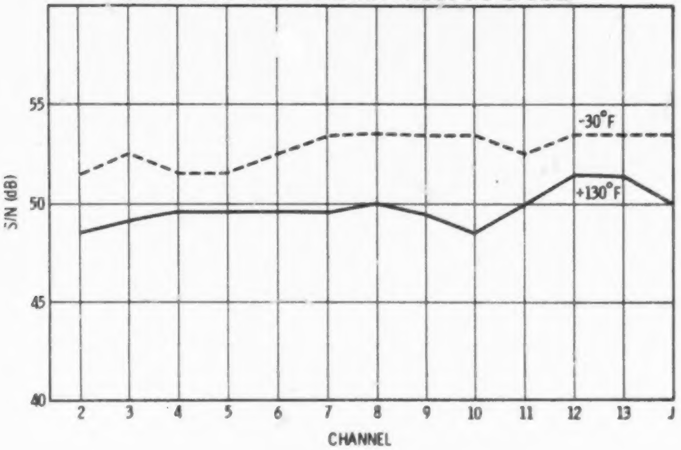

Figure 23

Figure 23 shows the overall AML system signal-to-noise ratio as a function of receiver temperature. It may be seen that lowering the receiver temperature significantly improves system noise figure. Measurements were made at a temperature of 130°F, which is 10° higher than the specification limit of 120°F. We do not wish to imply that the equipment should be operated beyond its specifications.

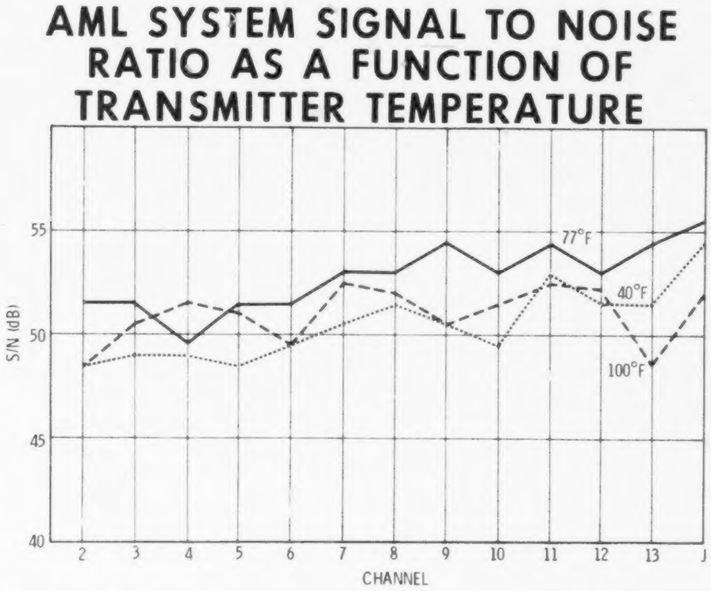

Figure 24

Finally, on Figure 24 is shown the effect on AML system signal-to-noise ratio as the transmitter temperature is varied. You might ask what will happen if the transmitter temperature should deviate from the limits shown here. Actually very little, certainly nothing from the reliability or signal quality viewpoints. The temperature limits specified are solely to keep the transmitter performance within its extremely stringent specifications.

This essentially concludes my discussion of the performance of the AML system operating by itself and let me turn now to the even more interesting topic of the combined operation of AML and conventional CATV systems. After all, the AML system does not feed subscribers directly, and its performance must therefore accommodate the further signal degradation encountered in the cable system itself. For the purpose of these composite performance measurements we employed the 32 amplifier cascade shown in Figure 25 in series with the AML system.

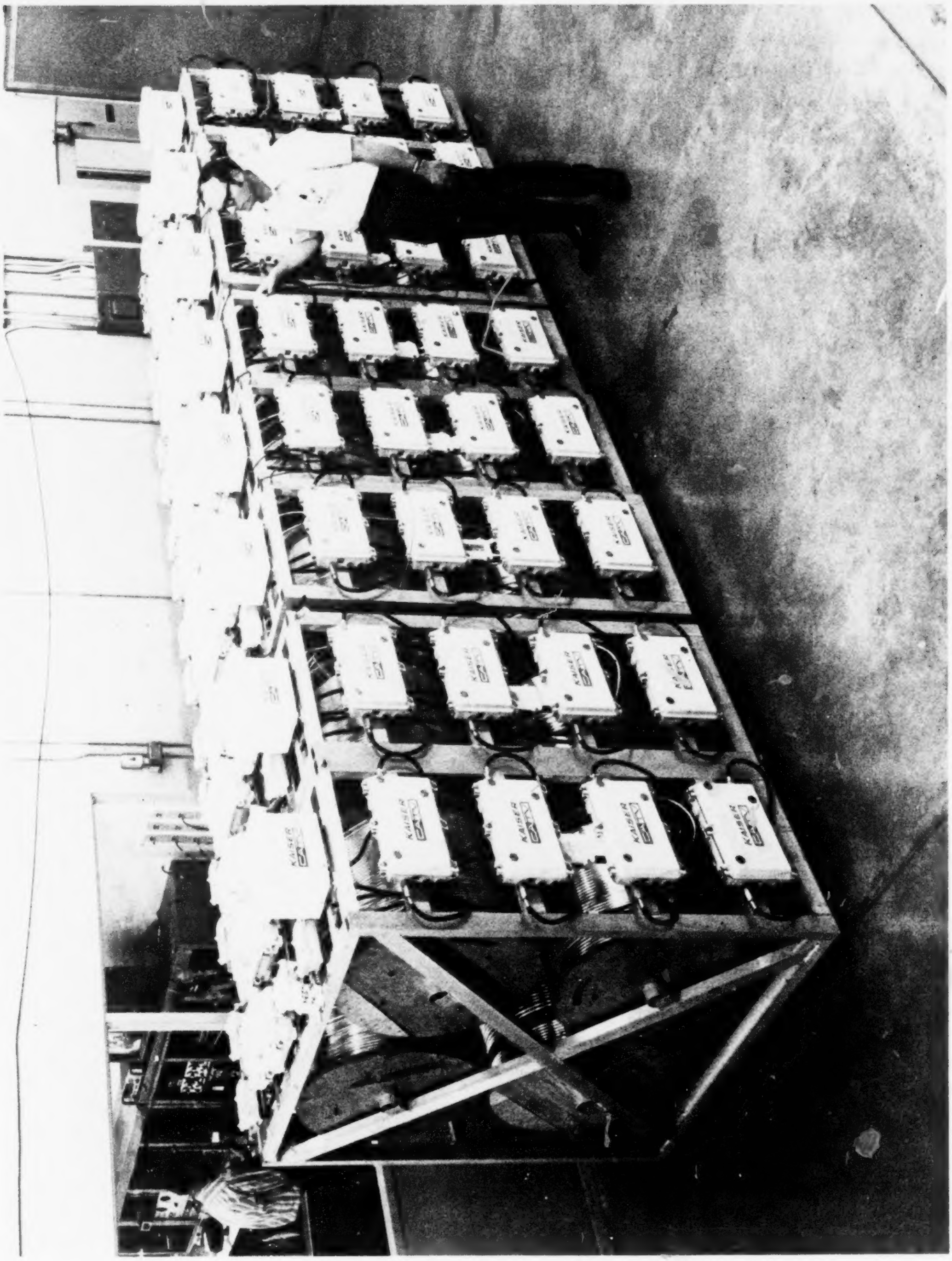
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Figure 25. 32 Amplifier Cascade

The cascade shown here contains 32 trunkline amplifiers and 32 reels of 412 cable having the appropriate 20 dB of attenuation at channel 13 between successive amplifiers. The amplifiers shown mounted in the vertical plane are the downstream or forward direction amplifiers employed in these tests. At the top of this cascade are shown upstream or reverse direction amplifiers together with their associated bypass filters. These are used for Subscriber Response System tests, and two-way AML tests, but not for the tests reported herein. Incidentally, this entire cascade of 32 amplifiers and 32 reels of cable is mounted on wheels and is usually rolled into the environmental test chamber which you saw earlier, together with the AML transmitter and receiver so that the composite performance of the AML system operating in conjunction with the amplifier cascade can be measured under temperature extremes.

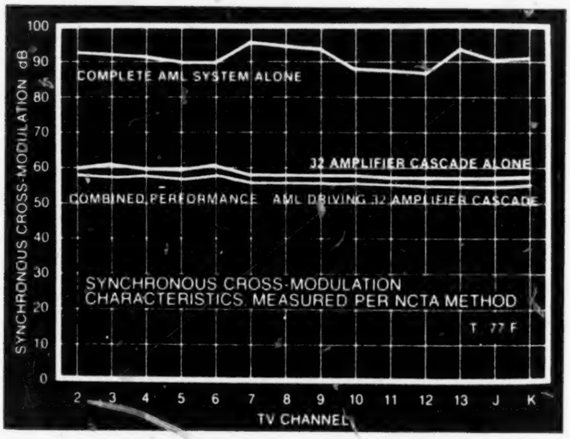

Figure 26. Composite Crossmodulation - AML Plus Amplifier Cascade

Figure 26 shows the results of the first of this series of measurements. The top curve shows the synchronous crossmodulation of the AML system operating by itself, the second curve shows the crossmodulation of the 32 amplifier cascade operating by itself, and the lowest curve shows the combined performance of the AML driving a 32 amplifier cascade. The deterioration is less than 3 dB for all channels because the crossmodulation of the AML is so much better than that of the cascade.

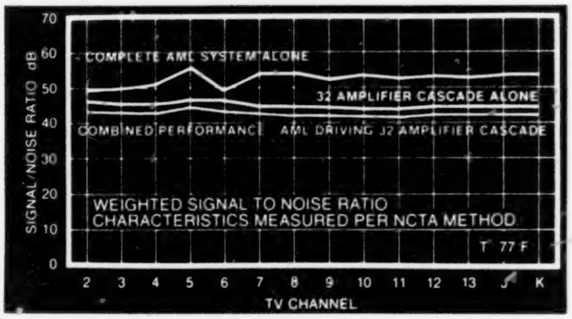

Figure 27. Composite S/N - AML Plus Amplifier Cascade

Figure 27 shows similar curves for signal-to-noise ratio. The top curve shows the signal-to-noise ratio for the AML system by itself, the middle curve shows the signal-to-noise ratio of the cascade by itself, and the bottom curve shows the combined performance of the AML driving a 32 amplifier cascade. In this case, the degradation of the cascade signal-to-noise ratio is also small, in spite of the fact that the differential between the AML system performance and the cascade performance is not quite as large for signal-to-noise as it is for crossmodulation. The reason for this is, of course, that signal-to-noise combinations are made on a power basis whereas crossmodulation combinations are made on a voltage basis. By way of illustration, two signal-to-noise ratios that are equal in magnitude combine for a composite signal-to-noise ratio that is only 3 dB worse, whereas two crossmodulation values that are equal in magnitude can combine to result in a composite performance that is 6 dB worse. Note, however, that the curves which I have shown are all plots of measurements and not of calculations.

The previous two illustrations showed the composite actual performance with a 32 amplifier cascade. The effect of different cascade lengths is shown on Figure 28.

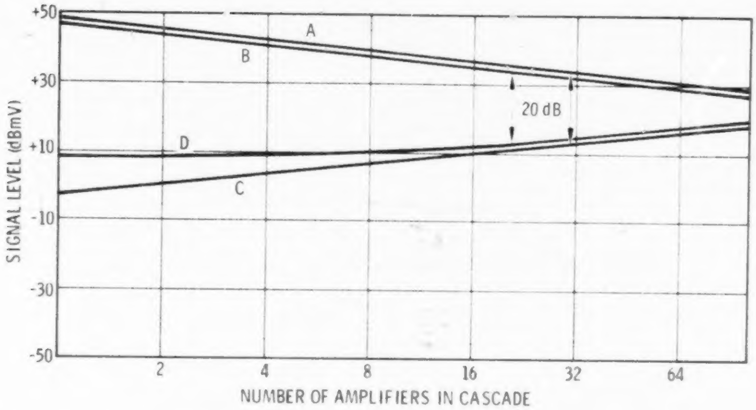

Figure 28. Composite AML Cascading Characteristics

The abscissa on this illustration is the number of amplifiers in the cascade plotted on a logarithmic scale. The vertical axis is signal level in dBmV. Curve "A" is the maximum trunkline amplifier output level for a cascade operating by itself, which cannot be exceeded if the synchronous crossmodulation at the end of the cascade is not to be worse than -57 dB down. Curve "B" is a similar curve for the maximum output level of the trunkline amplifiers in cases where an AML system is connected ahead of the amplifier cascade. The small spacing between Curves "A" and "B" is due to the fact that the crossmodulation of the AML is very much better than that of the amplifier cascade.

Curve "C" is the minimum input level of a cascade of trunkline amplifiers operating by itself which must be exceeded if the signal-to-noise ratio at the end of the cascade is not to be worse than 45 dB. Curve "D" is a similar curve for situations where an AML system is connected in series with the amplifier cascade. In this case the spacing between the curves does not begin to get small until the amplifier cascade gets rather long. This is, of course, the area of interest inasmuch as it is trivially easy to feed a short cascade.

Obviously if the upper sets of curves represent the maximum output level from the amplifiers, and the lower set of curves represents the minimum input level to the amplifiers, then the minimum separation between the upper and lower curves is equal to the gain of the amplifiers. This is in turn equal to the attenuation of the cable connecting successive amplifiers. This spacing is 20 dB at channel 13. The maximum cascade is shown in the illustration for both the cascade operating by itself as well as the cascade operating in series with an AML system. In the former case, the maximum length of the cascade is 31 amplifiers, and in the latter case it is 25 amplifiers. In a manner of speaking, the AML system may then be said to be equivalent to a cascade of 6 amplifiers. This is an over-simplification, however.

The crossmodulation of an AML system is much lower than that of a 6 amplifier cascade.

It should be noted that the reduction in the length of the tolerable cascade with AML does not represent a reduction in the area to be covered. On the contrary, since the AML can easily cover a distance of the order of 20 miles before the cascade even starts, the total distance to be covered with AML is three times as great as without and the total area or the number of subscribers which can be covered with the same quality of signal is nine times as large. Conversely, if the intention is to improve signal quality rather than to expand the system, the total length of amplifier cascades can be vastly reduced and signal quality correspondingly increased.

In conclusion, the AML local distribution multi-channel microwave system is finding increasing acceptance among sophisticated cable operators. Its performance fulfills the most exacting requirements.

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